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AF CENTER FOR ENVIRONMENTAL EXCELLENCE

Massachusetts Military Reservation

PLUME RESPONSE PROGRAM

FINAL

~~DRAFT~~

FS-12 CONTAINMENT SYSTEM DESIGN REPORT

VOLUME 1

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Prepared by:

Jacobs Engineering Group Inc.

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AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

MASSACHUSETTS MILITARY RESERVATION
PLUME RESPONSE PROGRAM

FS-12 CONTAINMENT SYSTEM

VOLUME I

DRAFT DESIGN REPORT

OCTOBER 1996

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1.0 INTRODUCTION

This Draft Design Report has been prepared for the United States Air Force Center for Environmental Excellence (AFCEE) as part of the U.S. Air Force (USAF) Installation Restoration Program (IRP) under the Remedial Action Contract No. F41624-94-D-8115 Delivery Order No. 25. The project described herein is one component of the Strategic Plan developed by the U.S. Air Force to remediate groundwater contamination at the Massachusetts Military Reservation (MMR) in Cape Cod, MA (AFCEE 1996). Specifically, this report addresses the capture and remediation of the Fuel Spill-12 (FS-12) plume located north and east of Snake Pond.

Numerous combinations of wells, well spacing and pumping rates were evaluated to determine their effectiveness in capturing and containing the existing FS-12 plume. The goal of the FS-12 plume containment project was to identify a network of extraction and reinjection wells that will capture as near to 100% of the plume as possible without unacceptable ecological, hydrological, or other impacts. A lessor capture ratio may be acceptable if necessary to reduce or eliminate ecological or hydrological impacts. Based on the extent and characteristics of the FS-12 plume as described in the Data Gap Technical Memorandum (OpTech 1996a) and a balanced assessment of beneficial and adverse impacts associated with groundwater pumping effects, a network of 30 extraction and 30 reinjection wells was proposed for the final design (OpTech 1996b).

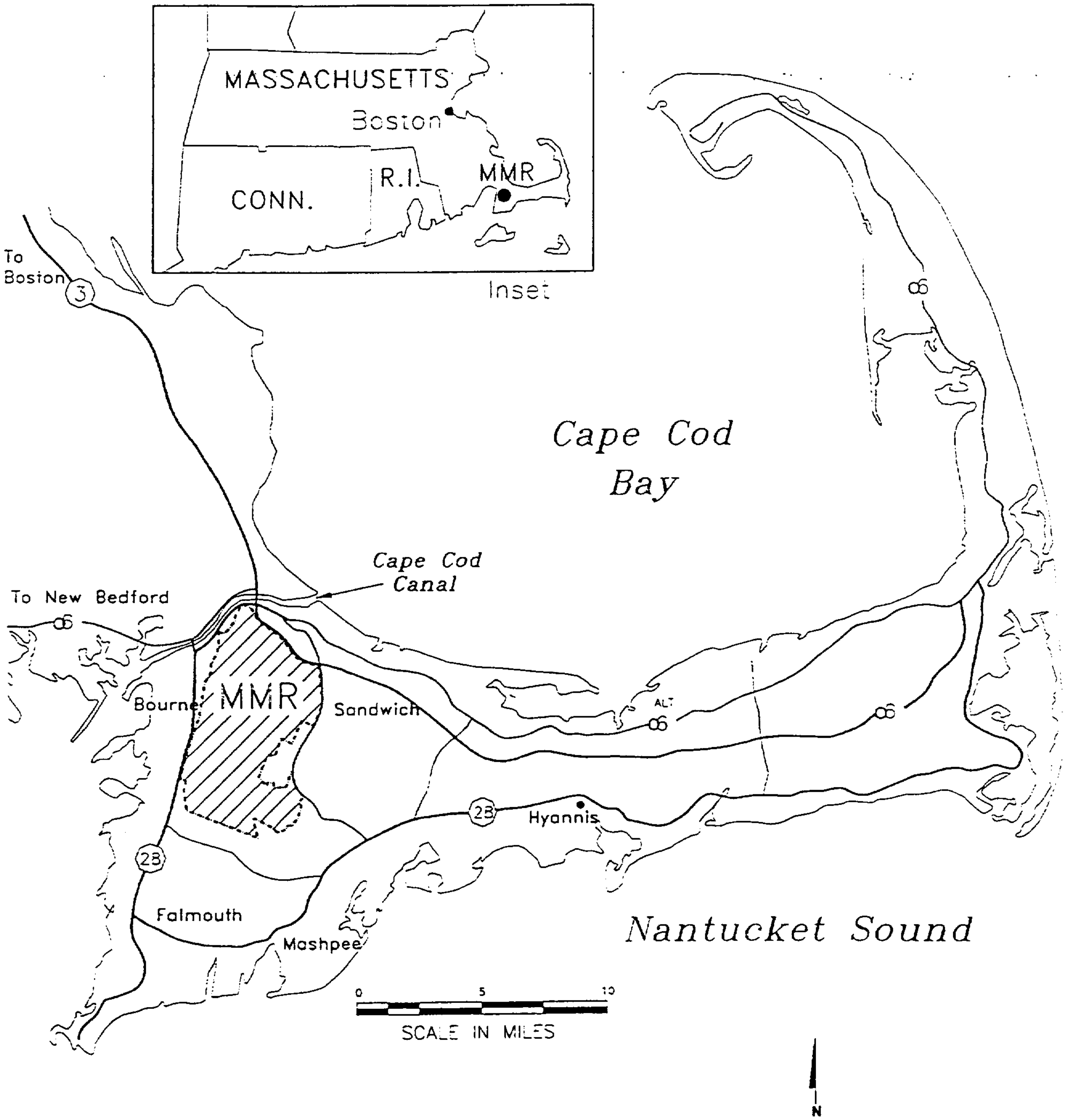
The purpose of This Draft Design Report is to present the extraction, treatment and reinjection (ETR) system design for the FS-12 groundwater plume at the MMR site, by providing the process design basis, the treatment process description, treatment system component details, process control and containment provisions, the groundwater extraction and reinjection system details and operation and maintenance requirements. This Draft Design Report also outlines anticipated activities associated with: system design refinement; and mitigation of

existing data gaps. As a preface to the discussion of the FS-12 ETR system design basis, a brief summary of the site and the project background is presented in the following sections.

1.1 MMR SITE LOCATION AND DESCRIPTION

MMR encompasses approximately 22,000 acres on western Cape Cod, Massachusetts, about 60 miles south of Boston (Figure 1-1). It is located in Barnstable County, and is bounded by the towns of Bourne, Falmouth, Mashpee, and Sandwich. The reservation houses various facilities and related operations of the following Department of Defense (DOD) branches: U.S. Coast Guard, U.S. Marine Corps, U.S. Army National Guard (ARNG [Camp Edwards]), U.S. Air Force, and U.S. Air National guard (ANG [Otis ANG Base]). Portions of the base are used by the Veterans Administration National Cemetery, the U.S. Department of Agriculture, and the Commonwealth of Massachusetts. Most facilities are in the southern portion of the reservation. The northern portion consists of several firing ranges which the ARNG uses for training with live ammunition.

Since its establishment in 1911, a variety of activities have been conducted on MMR, including troop training and deployment; fire-fighting training; ordnance development, testing and training; aircraft and vehicle operation and maintenance; and fuels transport and storage. Most activities can be associated with either mechanized army training, maneuvers and associated functions, or with military aircraft operations, maintenance, support, and associated functions. Operations on the reservation intensified during and just after World War II (1940 to 1946). From 1955 to 1970, a substantial number of surveillance and air defense aircraft operated out of the ANG portion of the reservation. Since that time the intensity of operations has slowed, and currently a single reserve fighter squadron trains out of this airfield.



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SITE LOCATION MAP

Massachusetts Military Reservation
Cape Cod, Massachusetts

10/14/96 Drawn By: KK File:..capefig.cdr

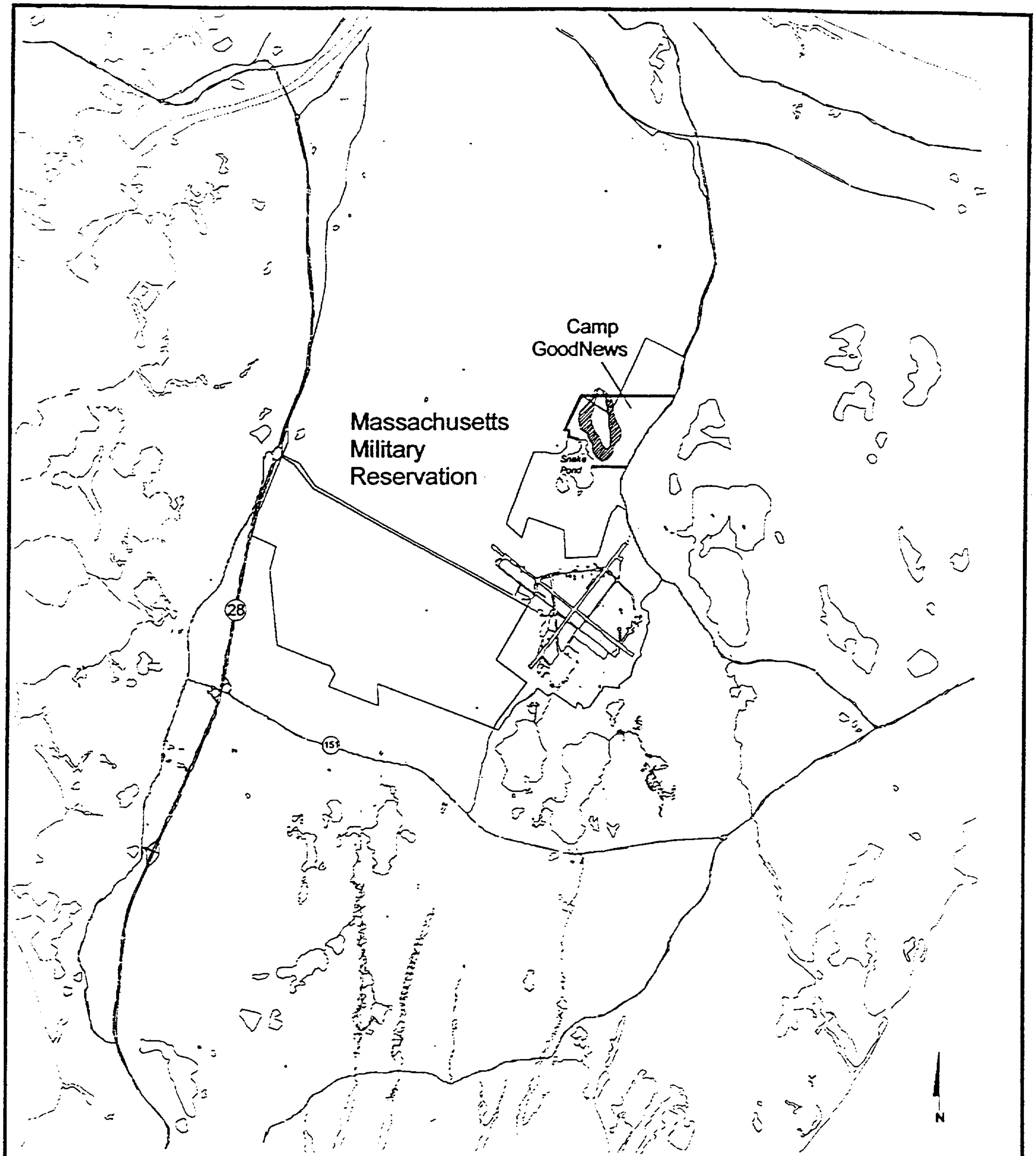
Figure 1-1

The FS-12 Plume Area lies in an area outside the bounds of MMR in the village of Forestdale, within the town of Sandwich, Massachusetts. It also includes most of Camp Good News (CGN), which is located along a portion of the eastern boundary of MMR (Figure 1-2). CGN is a privately owned, summer camp facility. Some permanent residential housing exists on private properties the property adjacent to CGN.

1.2 BACKGROUND FOR FS-12 DESIGN

The origin of the FS-12 groundwater contamination was a leak of approximately 70,000 gallons from a section of fuel pipeline at the intersection of Greenway Road and the western entrance to L-range (ASI 1992). Both aviation gas (AVGAS) and jet propellant 4 (JP-4) jet fuel were carried through the pipeline. The leaking section of the pipeline was repaired in 1972. Contamination associated with FS-12 was first detected in 1990 when the Sandwich Water District (SWD) detected hydrocarbon odors and volatile organic compounds (VOCs), including benzene, in groundwater at two exploratory wells installed off-base on the grounds of Camp Good News. The exploratory wells were installed as part of an effort to identify suitable locations for additional water supply production wells. The remedial investigation (RI) completed in 1993 concluded that fuel leaking from the pipeline had contaminated soil and groundwater in the immediate vicinity of Greenway Road (ASI 1992).

In 1994, the Senior Management Board, the Plume Containment Team, and representatives from the regulatory agencies agreed that a system to contain and treat 100 percent of the volatile organic compounds (VOCs) found in seven plumes at MMR, including FS-12, should be designed. In March 1995, OpTech, the prime contractor for the Air National Guard, initiated work on a 60 percent design for 100 percent containment of the seven groundwater plumes. The 60 percent design was completed in January 1996.



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MASSACHUSETTS MILITARY RESERVATION, CAMP GOODNEWS AND FS-12 PLUME

Massachusetts Military Reservation
Cape Cod, Massachusetts

10/11/96 Drawn By: KK File:...plumefig.cdr

Figure 1-2

However, during public review the 60 Percent Design was considered unacceptable by all parties because of adverse impacts on Cape Cod's sensitive ecosystems and sole-source aquifer. The Technical Review and Evaluation Team (TRET), includes a hydrological group and an ecological group established from a number of agencies and contractors, was assembled in March 1996 to technically evaluate the 60 Percent Design. The primary finding of the TRET's evaluation was that concurrent achievement of the ROD for Interim Action goal of simultaneous, 100 percent capture of all the plumes at their leading edges was not possible without significant negative environmental impacts. After reaching consensus that a new approach was needed, the TRET assisted in developing a new set of design criteria and containment strategies.

To avoid adverse ecosystem impacts associated with simultaneous, full containment of all plumes and to deal with plume data gaps, the TRET decided to recommend a design process that examined each plume individually. The TRET selected the following criteria to balance the design process:

- Avoid unacceptable toxicological risk from plume contaminants to human health and biological organisms;
- Avoid unacceptable impacts from the proposed containment strategy to the natural resources; and
- Avoid undesirable impacts on regional groundwater flow and flow paths of other plumes (i.e. avoid diverting or spreading other plumes into previously uncontaminated areas).

The recommendation from the TRET for the FS-12 plume was to design and install a pump and treat system to maximize plume capture, while minimizing impacts to Snake Pond and J. Braden Thompson plume.

From March 1996 to June 1996, OpTech and their modeling subcontractor P^2T (formerly Environmental Consulting Engineering [ECE]) performed a number of groundwater simulations to identify a groundwater extraction system to maximize

capture of the FS-12 plume while minimizing impacts to Snake Pond and the J. Braden Thompson plume. Based on the results of the computer modeling performed by P^2T, a network of 30 extraction and 30 reinjection wells was proposed for the FS-12 groundwater extraction network. The computer modeling that provided the basis for that network is described in the Plume Containment Design Groundwater Modeling Report (OpTech 1996b) submitted in late August 1996. An appendix to that report which focused on the FS-12 site was submitted in July 1996. Section 2.4.1 provides a summary of the groundwater modeling efforts performed by P^2T for FS-12.

In May 1996, during completion of the FS-12 modeling efforts by OpTech and P^2T, the U.S. Air Force (through AFCEE) became the lead agency for the MMR. As part of the plume response strategy, Jacobs Engineering Group Inc. (Jacobs) has been contracted to design plume containment/remediation systems for groundwater plumes at MMR, including FS-12.

Since May 1996 Jacobs became the prime AFCEE contractor at MMR, there have been five meetings regarding critical issues related to the FS-12 ETR system. A brief synopsis of the meetings is included below:

- May 1996: AFCEE, TRET, JPAT reviewed and adopted the 30 extraction well and 30 reinjection well ETR system. This became the basis for upcoming engineering.
- August 6, 1996: AFCEE, EPA, MDEP, and the TRET (hereafter referred to as Stakeholder) reviewed appendices of OpTech's FS-12 and SD-5 modeling reports. These appendices included detailed information regarding different well scenarios that were evaluated to achieve remedial objectives in each of the plumes. One of the primary conclusions of the August 6, 1996 meeting was that an additional meeting was required to review the main body of the OpTech Modeling Report.
- August 28, 1996: Stakeholders reviewed the main body of OpTech's FS-12 and SD-5 modeling reports. Model formulation, calibration, and sensitivity analysis strategies were discussed during the meeting. Following the August

28, 1996 meeting, stakeholders requested specific FS-12 and SD-5 meetings to evaluate in more detail the design basis of the proposed ETR systems.

- September 30, 1996: Stakeholders were presented the design basis of the FS-12 ETR system. Specific topics of discussion included the appropriateness of modeling parameters and the need to fill data gaps before construction of the FS-12 ETR system. Specific data gap well locations were identified by the participants.

- October 8, 1996: Stakeholders discussed potential chemical and hydraulic impacts that the FS-12 ETR system could have on ecological resources, especially Snake Pond. Potential impacts included changes in temperature, pH, total organic carbon, dissolved oxygen, essential nutrient concentrations, and water table variations. It was agreed upon that the treatment process should include re-oxygenation of the plant effluent to maintain ambient oxygen concentrations in groundwater inflow to Snake Pond. Further additions to the treatment process may be identified in the future as site-specific ecological data is collected and evaluated over the next year. The most probable addition to the treatment plant are currently identified as pH adjustment and the addition of Total Organic Carbon (TOC).

- Based on input from stakeholders over the past several months, the FS-12 ETR system design is anticipated to proceed on schedule. Although many issues have been discussed, and additional modeling and data gap efforts were suggested by stakeholders, no critical flaws in the FS-12 ETR system design have been identified. The next section outlines the basis of the recommended FS-12 ETR system design.

2.0 DESIGN BASIS

The FS-12 ETR system has a number of objectives (Strategic Plan AFCEE, 1996) which include:

- Design, construct, and operate a full-scale ETR system;
- Contain, capture, and remediate the FS-12 plume;
- Minimize adverse impacts on Snake Pond and its surrounding environment;
- Monitor performance of treatment system;
- Avoid influencing the remedial system on the J. Braden Thompson plume;
- Minimize disturbance to private property;
- Monitor performance of treatment system; and
- Monitor groundwater quality to assess performance and assist future design at other sites.

These objectives, in combination with regulatory requirements and the site conditions form the basis for the FS-12 ETR system design. The last two bullets identify performance monitoring objectives and are not addressed in this report. These topics will be presented in the Draft Performance Monitoring Plan to be submitted in December 1996. As discussed in Section 1.2, Background For FS-12 Design, a network of 30 extraction and 30 reinjection wells was determined to provide a satisfactory balance of project objectives, and that system was described in the Plume Containment Design Groundwater Modeling Report in August 1996. In addition, as discussed in Section 1.2, Background For FS-12 Design, following submittal of the Plume Containment Design Groundwater Modeling Report in August 1996, various aspects of the design basis for the FS-12 ETR system have since been discussed in four separate technical meetings. These meetings have resulted in the commitments for additional data collection activities and modeling simulations to verify or refine the proposed FS-12 ETR system network of 30

extraction and 30 reinjection wells changed. Also, access to Camp good News was obtained after Labor Day, thus allowing for detailed site inspections, construction surveys and discussions with the property owner regarding long-term access and right of entry. As a result, this Draft Design Report presents the network of 30 extraction and 30 reinjection wells as the basis for the FS-12 ETR system design with the understanding that finalizing the design will be an iterative process. The following items may be used to refine the FS-12 ETR system design basis prior to construction, if necessary:

- Jacobs is in the process of evaluating aquifer pump test data recently collected at FS-12. Section 2.5.4 provides more detail on the preliminary results of the OpTech FS-12 pumping test.
- Jacobs will collect additional field data as described in Section 2.5.1, to better define the baseline and contaminant concentrations of the plume.
- Jacobs will continue to address property access issues to ensure that construction of the FS-12 ETR system will alleviate Camp Good News property owner concerns.
- Jacobs will evaluate alternate locations for reinjection wells located adjacent to the source area of the reinjection wells along the J. Braden Thompson Plume to ensure that disturbance of the plume is minimal. Section 2.4.2 provides more detail on the location of reinjection wells in the vicinity of the J. Braden Thompson Plume that are currently under evaluation.
- Jacobs will continue to evaluate ecological issues related to construction of the FS-12 ETR system. Section 2.5.5 provides more detail on ecological issues related to FS-12.
- Stakeholder input on the FS-12 design will continue to be evaluated.

As additional information becomes available, Jacobs will update the current FS-12 groundwater model to refine groundwater extraction and reinjection well locations, as necessary. Final modeling simulations, including modifications to

the FS-12 ETR system proposed herein, will be presented to stakeholders for evaluation and approval.

It is important to recognize that although design refinements are anticipated, these refinements are not expected to significantly change the conceptual basis for the FS-12 ETR system described in this Draft Design Report. To compensate for design uncertainties, the FS-12 ETR system design includes flexibility in sustainable system operating flow rates, and acceptable influent water quality. The following sections include a discussion of site conditions, modeling efforts, data gap collection efforts, treatment plant water quality considerations, and design limitations related to the basis of the FS-12 ETR system design.

2.1 FS-12 Plume

The primary constituents in the FS-12 plume are benzene and ethylene dibromide (EDB). Figures 2-1 and 2-2 show in plan view the extent to which maximum contaminant levels (MCLs) have been exceeded for EDB and benzene, respectively, as of November 1995 (OpTech 1996a).

Screened auger and sampling data collected during the data gap field effort indicate that both the benzene and EDB plumes continue to migrate south-southeast. The leading edge of the benzene plume has migrated to the Camp Good News entrance road. Benzene in monitoring well GMW-20 increased from a concentration of 43 micrograms per liter (µg/L) (April 1993) to 1,800 µg/L (November 1995) (OpTech 1996a).

The leading edge of the EDB plume has migrated to J. Braden Thompson Road. EDB in monitoring wells GMW-20 and GMW-40 has increased from an estimated concentration of 144 µg/L (April 1993) to 300 µg/L (November 1995), and 0.89 µg/L (March 1993) to 39 µg/L (August 1995), respectively.

The majority of the FS-12 plume is migrating through glacial outwash sands and gravels. As the FS-12 plume migrates, the top of the plume descends from the

water table (68 feet mean sea level [MSL]) to approximately 118 feet below the water table (–50 feet MSL) over a distance of about 5,000 feet. Plume contaminants have been detected in the upper 10 to 20 feet of the glacial lacustrine sediment underlying the outwash sands and gravels. The maximum projected width of the entire plume front normal to groundwater flow is approximately 2,300 feet, and the maximum thickness of the plume is approximately 150 feet.

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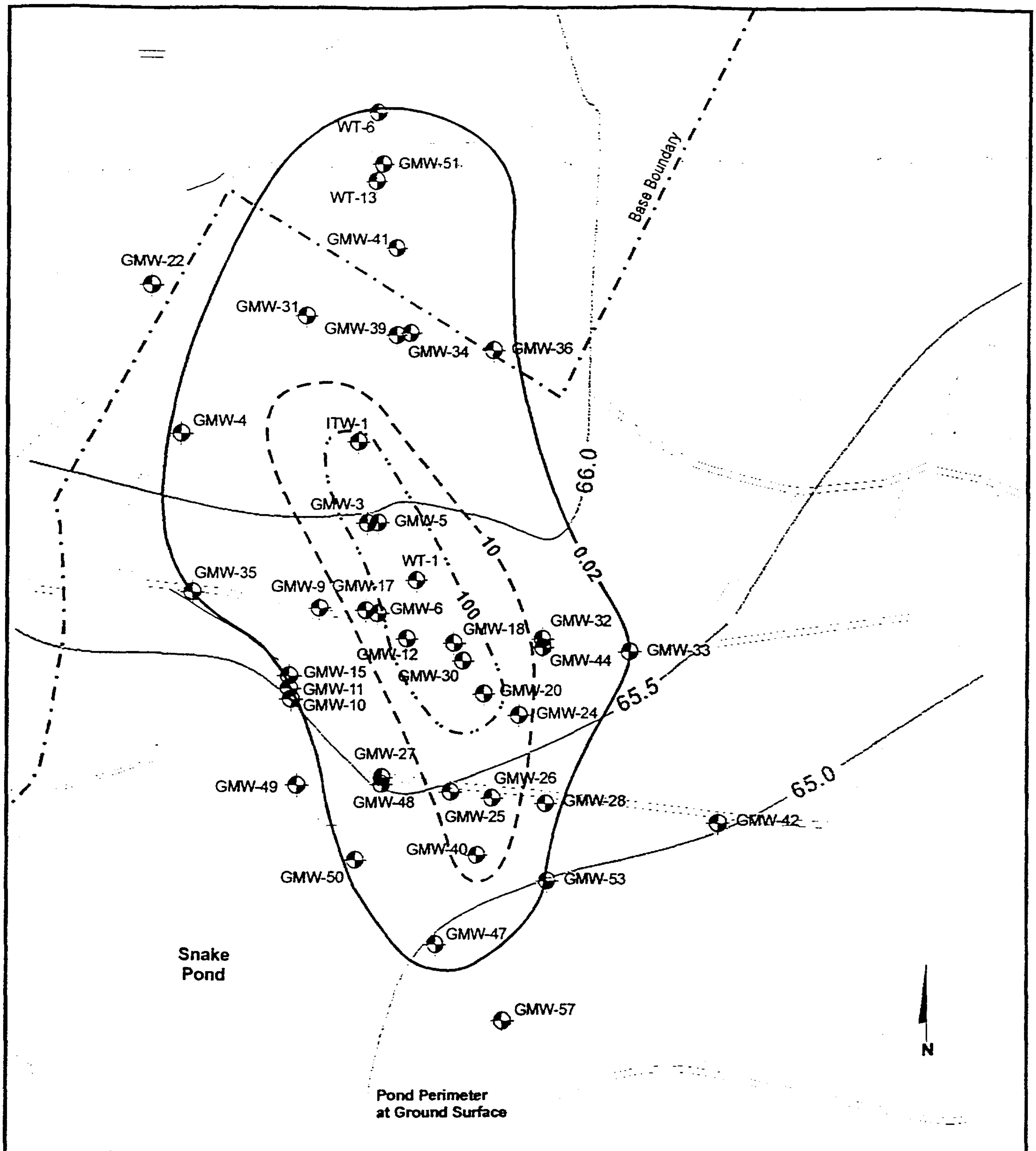

Sample Existing GW Monitoring Well

Line of Equal Groundwater Contamination

Isoconcentration Contour Line of EDB (concentration in $\mu g/L$)

0.02

10

100

0 700

Scale In Feet 1:8400

Maximum contaminant level for EDB=0.02 $\mu g/L$ (Massachusetts MCL)

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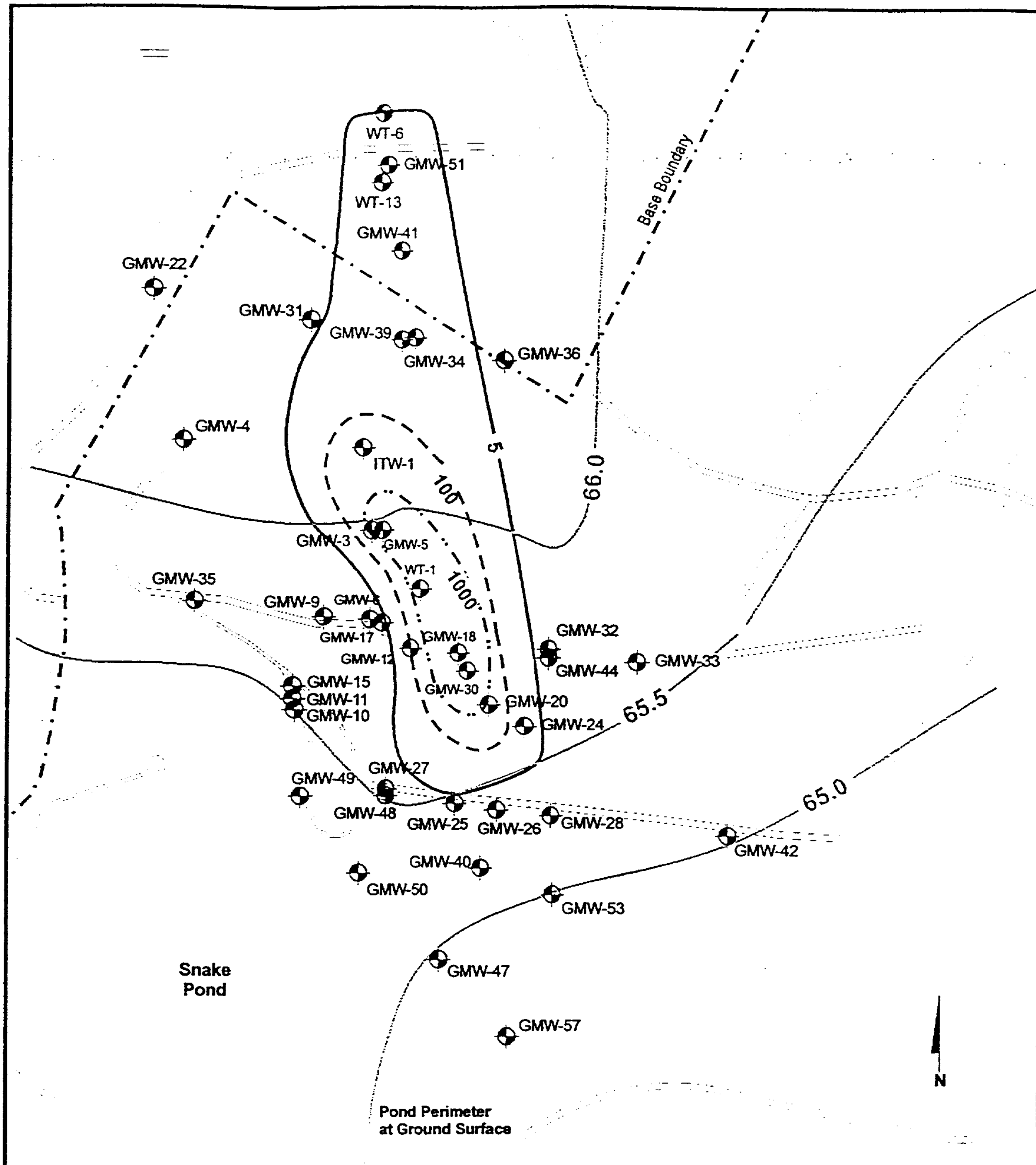
FUEL SPILL 12
EDB MCL EXCEEDANCE
ISOCONCENTRATION MAP

Massachusetts Military Reservation
Cape Cod, Massachusetts

10/11/96 Drawn By: KK File: .edbfs12c.cdr

Figure 2-1



Sample Existing GW Monitoring Well

Line of Equal Groundwater Elevation

Isoconcentration Contour Line of EDB (concentration in µg/L)

5

100

1000

0 700

Scale In Feet

1:8400

Maximum contaminant level for EDB=0.02 µg/L (Massachusetts MCL)

JE JACOBS ENGINEERING

FUEL SPILL 12
BENZENE MCL EXCEEDANCE
ISOCONCENTRATION MAP

Massachusetts Military Reservation
Cape Cod, Massachusetts

10/11/96 Drawn By: KK File:..edbfs12d.cdr

Figure 2-2

2.2 FS-12 GEOLOGY

Geologic interpretations of the FS-12 Study Area are based on soil sampling of both the unsaturated and saturated zones, boring log data obtained from split-spoon samples, auger cuttings, and variations in drill rates. Bedrock was not encountered during drilling activities at FS-12.

A zone of surface and weathered residual soil of approximately 2 to 5 feet is common in the study area. The interval typically consists of yellowish-brown to dark-brown horizons of silty clay or clayey silt, with variable mixtures of fine sand and/or organic matter.

Underlying the soil zone is the upper sand and gravel outwash deposits of the Mashpee Pitted Plain (ASI 1995). The substrata are unconsolidated and typically consist of light-brown or yellowish-orange-brown sand with minor amounts of gravel, and little to no fines (silt and clay). The sand is mostly weathered quartz with some feldspar. The grains are typically well-sorted, predominantly medium-grained, and sub-angular to sub-rounded. Trace amounts of weathered micas (muscovite and biotite) and hornblende may be present. The gravel component typically ranges between 0 to 25 percent of the lithology. It is typically poorly sorted with clasts ranging in size from fine gravel to cobbles or boulders. The clasts are predominantly weathered granite (ASI 1995).

Locally, an abundance of coarse gravel (cobbles to boulders) is common in the uppermost 30 feet of substrata. Discontinuous zones of gravel may occur throughout the outwash deposits. The sands and gravels generally lack cementation between sediment grains. This is commonly exhibited by the occurrence of flowing or "heaving" sands below the water table. Porosities typically range from 30 to 40 percent (Leblanc 1984). The overall Unified Soil Classification System (USCS) designation for the deposits is SP: poorly-graded

sand or gravely sand with little or no fines. The deposits are typical of high-energy fluvial environments, distinctive of pro-glacial outwash plains.

Below the uppermost 130 feet of sand and gravel deposits, intervals of fine-grained glaciolacustrine sediments were noted, particularly at depths ranging between approximately 130 to 215 feet below ground surface (bgs) (i.e., +20 to –65 feet MSL). Bedrock was not encountered during drilling activities at FS-12. Several borings penetrated approximately 20 to 25 feet of dense deposits of fine sand and slit. These sediments typically consist of gray to brownish-gray silty to sandy clay, clayey silt and sand, or silty sand. The deposits are indicative of restricted, low-energy glaciolacustrine environments.

2.3 FS-12 HYDROGEOLOGY

The total thickness of the saturated zone in the study area is estimated to be in excess of 200 feet. Penetration by auger drilling was limited to the uppermost 210 feet. The occurrence of low-permeability, fine-grained deposits within the aquifer indicate the existence of vertical and horizontal heterogeneity and therefore anisotropic flow conditions.

Groundwater in the study area is unconfined, with an average depth to groundwater of 70 feet. The water table is exposed at the surface in Snake Pond, delineating the southwestern boundary of the FS-12 area. The general direction of groundwater flow appears to shift slightly with seasonal fluctuations in aquifer recharge; however, the groundwater generally flows south to southeast. Groundwater elevation contours at FS-12 are included in Figures 2-1 and 2-2. The horizontal flow gradient generally ranges from 0.00025 to 0.0006 foot per foot (ft/ft). During the late summer or early fall, groundwater enters Snake Pond from the northwest, north, and northeastern sides. During the spring, groundwater inflow to the pond appears to be predominantly from the northwest and north.

One of the man-made features affecting the water table elevations in the southwest corner of the study area is the SWD Weeks Pond Well No. 5. The pumping rates for the Weeks Pond Well are normally 700 gallons per minute (gpm) for 6 hours each day; however, the duration of pumping is adjusted as needed to meet water usage demands (higher in summer). Final groundwater modeling simulations performed for FS-12 included the Weeks Pond well operating continuously at 700 gpm to ensure that the ETR system would still achieve plume capture objectives during peak water demand periods.

Vertical gradients were calculated from seven sets of cluster wells at the site. Well clusters located between 100 and 800 feet (predominantly northeast) from Snake Pond all showed slight upward vertical gradients ranging from 0.0002 to 0.006 ft/ft (ASI 1995). Well clusters located between 1,050 and 1,520 feet (predominantly northeast) from Snake Pond all showed slight downward gradients ranging from 0.001 to 0.002 ft/ft (ASI 1995).

Injection and pumping tests previously performed at FS-12 were reviewed to aid in the Remedial Design:

- Advanced Sciences, Inc. (ASI) and Hydrogeologic conducted a 72-hour pump test at the FS-12 study area in December 1993. The pumped well was approximately 740 feet northeast of monitoring well GMW-47. The overall horizontal hydraulic conductivity for the aquifer ranged from approximately 240 to 370 feet per day (ft/day), with an average of 320 ft/day. Vertical hydraulic conductivity ranged from 15 to 190 ft/day, with an average of approximately 75 ft/day. Specific yield ranged from 0.8 to 18.4 percent, with an average of 9 percent. Transmissivity ranged from 26,000 to 40,000 square feet per day (ft2/day), with an average of 35,000 ft2/day.
- A pumping step-test, injection step-test, 72-hour constant rate simultaneous injection/extraction test (and recovery period) and post-injection step-test were performed by OpTech immediately northwest of Snake Pond. The purpose of

these tests were to evaluate aquifer response to simultaneous extraction and injection adjacent to the pond with particular interest in the degree of groundwater table mounding created at the injection well site.

- In addition, a step injection test was recently conducted southwest of Snake Pond by OpTech to evaluate short-term aquifer response and specific injectivity and to examine if there are significant differences in aquifer characteristics across the FS-12 study area. Preliminary results from these tests indicate that transmissivities and hydraulic conductivity values northwest of Snake Pond may be higher than previous pump test locations. However, the results from these tests have not been finalized.

2.4 FS-12 MODELING

Groundwater modeling has served as one of the primary tools for evaluating the basis of the FS-12 ETR system design. By inputting the site hydrogeologic conditions with modifications as appropriate to achieve model calibration, and using particle tracking to simulate the extent of the EDB plume above MCLs, various extraction and reinjection well pumping and injection rates, locations, and screen depths have been simulated to aid in the design of the FS-12 ETR system. The Plume Containment Design Groundwater Modeling Report (OpTech 1996b) provides a detailed discussion of FS-12 model development and utilization for the FS-12 ETR system design. The following sections provide a summary of modeling efforts for FS-12, justification for proposed extraction and reinjection well locations, pumping/injection rates, and screen intervals, modeling uncertainties, and anticipated future modeling efforts.

2.4.1 Summary of Modeling Efforts for FS-12

As discussed in Section 1.2, Background for FS-12 Design, the initial objective of groundwater modeling efforts for MMR was to capture 100 percent of all

groundwater contamination from seven groundwater plumes, including FS-12. Following submittal of the 60 percent design it was determined that 100 percent capture of all groundwater contamination at MMR could result in adverse impacts to Cape Cod's sensitive ecological system and sole source aquifer. As a result, the main objectives of the groundwater modeling efforts following submittal of the 60 percent design were the following, in order of importance (OpTech 1996):

- Maximize contaminant capture of the FS-12 plume, protecting downgradient receptors with containment wells toward the leading edges of the plume and achieving mass reduction by installing additional wells in areas of higher contaminant concentrations;
- Minimize hydrologic impacts on nearby surface water (mainly Snake Pond);
- Minimize influence on movement of the J. Braden Thompson plume;
- Emphasize constructability and minimize impact to surrounding land;
- Minimize recapture of injected, treated groundwater; and
- Minimize pumping rates.

Since some of these objectives are conflicting, the basis of the FS-12 modeling efforts was to achieve a balance between the objectives.

In order to identify an efficient ETR system that satisfied the established design criteria, groundwater modeling was conducted using the code FRAC3DVS (Therrien, R. et al., 1994). Hydraulic conductivity values used for FS-12 modeling were developed from aquifer pumping and slug tests and adjusted during model calibration to obtain an acceptable match between modeled and observed groundwater elevations and stream flow measurements. To provide an additional model check, particle tracking was also performed to help evaluate if the model accurately predicted with reasonable accuracy the rate and direction of plume migration over time. Modeling details are provided in OpTech, 1996b.

Following model construction and calibration, fifteen different ETR schemes were developed and evaluated. The percent of contaminant mass captured and water table drawdown were two critical evaluation criteria for the alternatives assessed by the model.

The following bullets provide a brief summary of the simulations performed:

- Scenarios 1-8 simulated by the model minimized well spacing and utilized the concept of axial (wells located in concentrated portion of plume) and toe (wells located at the downgradient edge of the plume) extraction fences. Scenarios 1-8 did not capture the western portion of the plume and capture of the highest plume concentrations was inefficient.
- Scenarios 9-14 simulated by the model emphasized maximum plume capture, minimized disturbance to Snake Pond, while enhancing plume removal efficiency and western plume capture. Scenarios 10-14 also considered constructability, especially along Snake Pond. Scenario 14 provided the best fit among the criteria considered.
- Scenario 15 was the final scenario evaluated and was essentially the same as Scenario 14 with proposed well locations moved closer to existing roads to address construction concerns.

Scenario 15 consists of 30 extraction wells pumping at a design rate of approximately 830 gpm, and 30 injection wells pumping the same volume back into the aquifer following treatment. Scenario 15 is the recommended basis for the FS-12 ETR well network presented in this Draft Design Report. Table 2-1 presents the well locations, screen depths, and pumping rates for Scenario 15.

2.4.2 Well Locations

Figure 2-3 outlines a plan view of the network of 30 extraction and 30 reinjection wells proposed for the FS-12 ETR system design. The extraction well field

consists of three principal components, an axial extraction well fence (divided into north and south sections) to enhance plume capture near the highest detected levels of groundwater contamination (extraction wells EW-10 through EW-19), a western extraction fence to capture the western portion of the FS-12 plume (extraction wells EW-1 through EW-9), and a toe extraction fence to capture the southern portion of the plume (extraction wells EW-20 through EW-30). The three extraction well fences are designed to capture all groundwater contamination above MCLs attributed to the FS-12 source area. The entire extent of capture required to achieve this objective is defined by EDB, the largest groundwater plume at FS-12 as outlined on Figure 2-3. All other groundwater contaminants above MCLs are contained within the boundaries of the extent of EDB contamination.

TABLE 2-1
FS-12 EXTRACTION/REINJECTION WELLS

North Reinjection Wells (240 gpm)

Easting (coordinates)	Northing (coordinates)	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Pump Rate (gpm)
867150	252140	30	-30	40
867290	252120	30	-30	40
867450	252120	30	-30	40
867630	252100	30	-30	40
867810	252060	30	-30	40
867970	252000	30	-30	40

Central Reinjection Wells (420 gpm)

Easting (coordinates)	Northing (coordinates)	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Pump Rate (gpm)
868050	251780	30	-30	40
868090	251580	30	-30	50
868050	251400	30	-30	60
868130	251220	30	-30	70
868210	250920	30	-30	60
868370	250800	30	-30	60
868510	250580	30	-30	40
868550	250400	30	-30	40

Toe Reinjection Wells (170 gpm)

Easting (coordinates)	Northing (coordinates)	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Pump Rate (gpm)
868710	250300	5	-60	10
868910	250260	5	-60	10
869110	250240	5	-60	10
869170	250340	5	-60	10
869270	250380	5	-60	10
869390	250400	5	-60	10
869450	250480	5	-60	10
869550	250520	5	-60	10
869630	250580	5	-60	10
869710	250600	5	-60	10
869810	250660	5	-60	10
869890	250720	5	-60	15
869970	250760	5	-60	15
870150	250840	5	-60	10
870170	251040	5	-60	10
870170	251220	5	-60	10

TABLE 2-1, continued

North Axial Extraction Wells (-105 gpm)

Easting (coordinates)	Northing (coordinates)	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Pump Rate (gpm)
868590	252820	5	-60	-25
868630	252660	5	-60	-25
868630	252520	5	-60	-25
868650	252380	5	-60	-30

Western Extraction Wells (-315 gpm)

Northing (coordinates)	Easting (coordinates)	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Pump Rate (gpm)
867270	252400	5	-60	-35
867450	252400	5	-60	-30
867610	252380	5	-60	-30
867770	252340	5	-60	-30
867910	252300	5	-60	-35
868070	252240	5	-60	-35
868230	252240	5	-60	-35
868350	252240	5	-60	-40
868470	252180	5	-60	-40

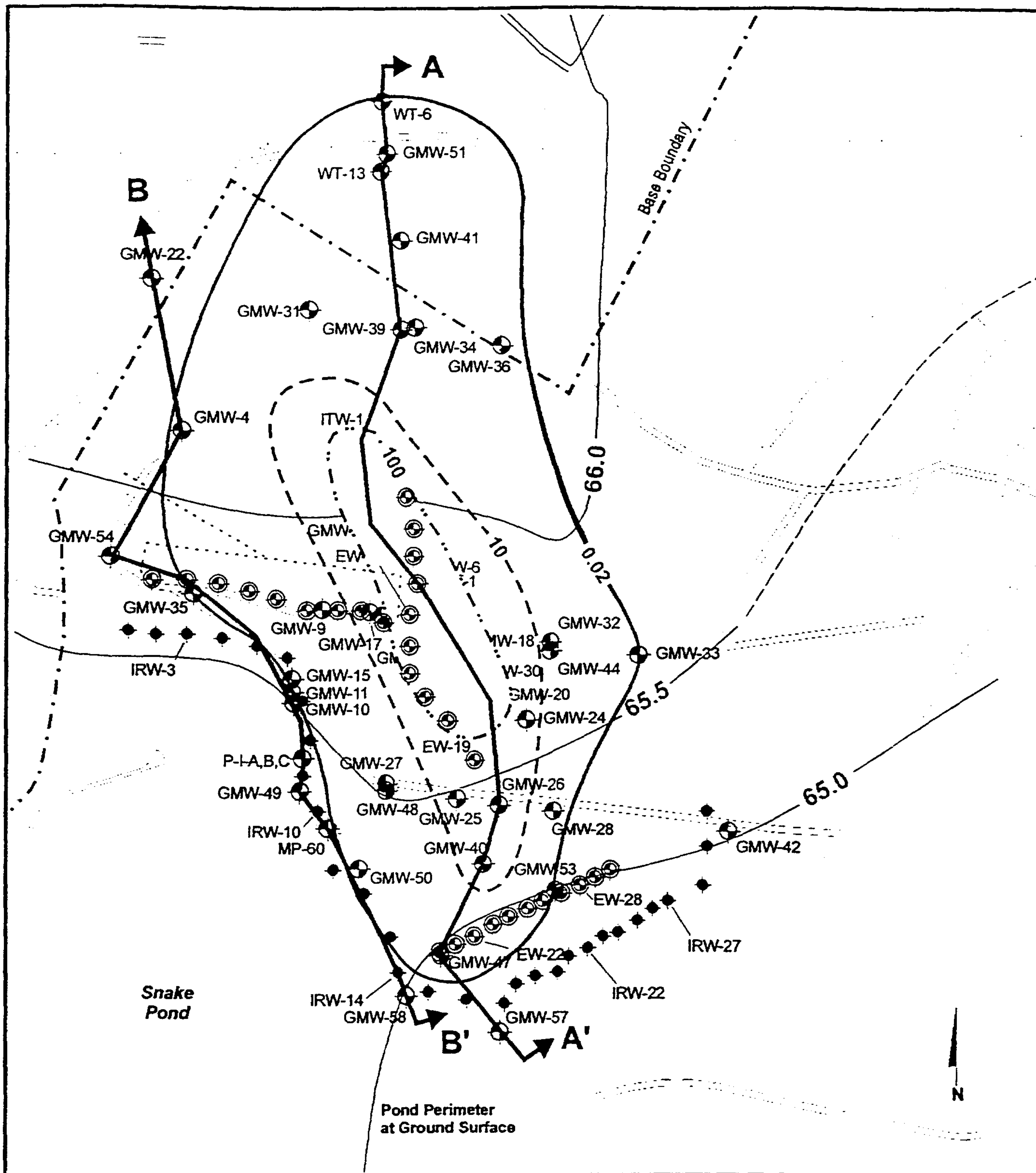
South Axial Extraction Wells (-155 gpm)

Easting (coordinates)	Northing (coordinates)	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Pump Rate (gpm)
868610	252220	5	-60	-25
868610	252060	5	-60	-25
868610	251920	5	-60	-25
868690	251800	5	-60	-25
868810	251680	5	-60	-25
868950	251480	5	-60	-30

Toe Axial Extraction Wells (-255 gpm)

Easting (coordinates)	Northing (coordinates)	Top of Screen (ft msl)	Bottom of Screen (ft msl)	Pump Rate (gpm)
868770	250500	5	-60	-25
868850	250540	5	-60	-25
868950	250580	5	-60	-25
869050	250640	5	-60	-25
869130	250680	5	-60	-20
869230	250720	5	-60	-25
869310	250760	5	-60	-20
869410	250800	5	-60	-25
869510	250840	5	-60	-25
869590	250880	5	-60	-25
869670	250920	5	-60	-25

Notes:
ft msl feet mean sea level
gpm gallons per minute



Existing Monitoring Well

Extraction Well

Reinjection Well

0 700

Scale In Feet
1:8400

—— Line of Equal Groundwater Contamination

Isoconcentration Contour Line of EDB (concentration in $\mu g/L$)

—— 0.02

— — — 10

— ·· — 100

Maximum contaminant level for EDB=0.02 $\mu g/L$ (Massachusetts MCL)

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FUEL SPILL 12
EDB MCL EXCEEDANCE
ISO CONCENTRATION AND
CROSS-SECTION LOCATION MAP
Massachusetts Military Reservation
Cape Cod, Massachusetts

10/14/96 Drawn By: KK File:..edbfs12a.cdr

Figure 2-3

The reinjection well field consists of two principal components, a western reinjection well fence (divided into north and central sections) located along the northern and central portion of Snake Pond (IRW-1 through IRW-14) and a toe reinjection well fence located directly south of the FS-12 plume southern boundary (IRW-15 through IRW-30). The western reinjection well fence is designed to minimize the impact of groundwater extraction on Snake Pond and enhance plume capture. The southern reinjection well fence is designed to minimize the impact of groundwater extraction from FS-12 on the J. Braden Thompson Plume.

Based on the groundwater modeling results for FS-12 and discussions with stakeholders, several areas within the EDB plume still require additional characterization to ensure the extent of the plume is accurately defined and the proposed extraction and reinjection well scheme is sufficient to meet the objectives of complete capture of all groundwater contamination above MCLs. These areas include the western FS-12 plume in the vicinity of Snake Pond, the extreme eastern plume extent, and the southern plume boundary in the vicinity of the J. Braden Thompson Plume. Placement of the southern reinjection well fence relative to the source requires further investigation to ensure that the proposed FS-12 ETR system has minimal impact on the that plume. Section 2.5.1 provides a detailed discussion of data collection activities that will be performed prior to construction of the FS-12 ETR system to address these data gaps.

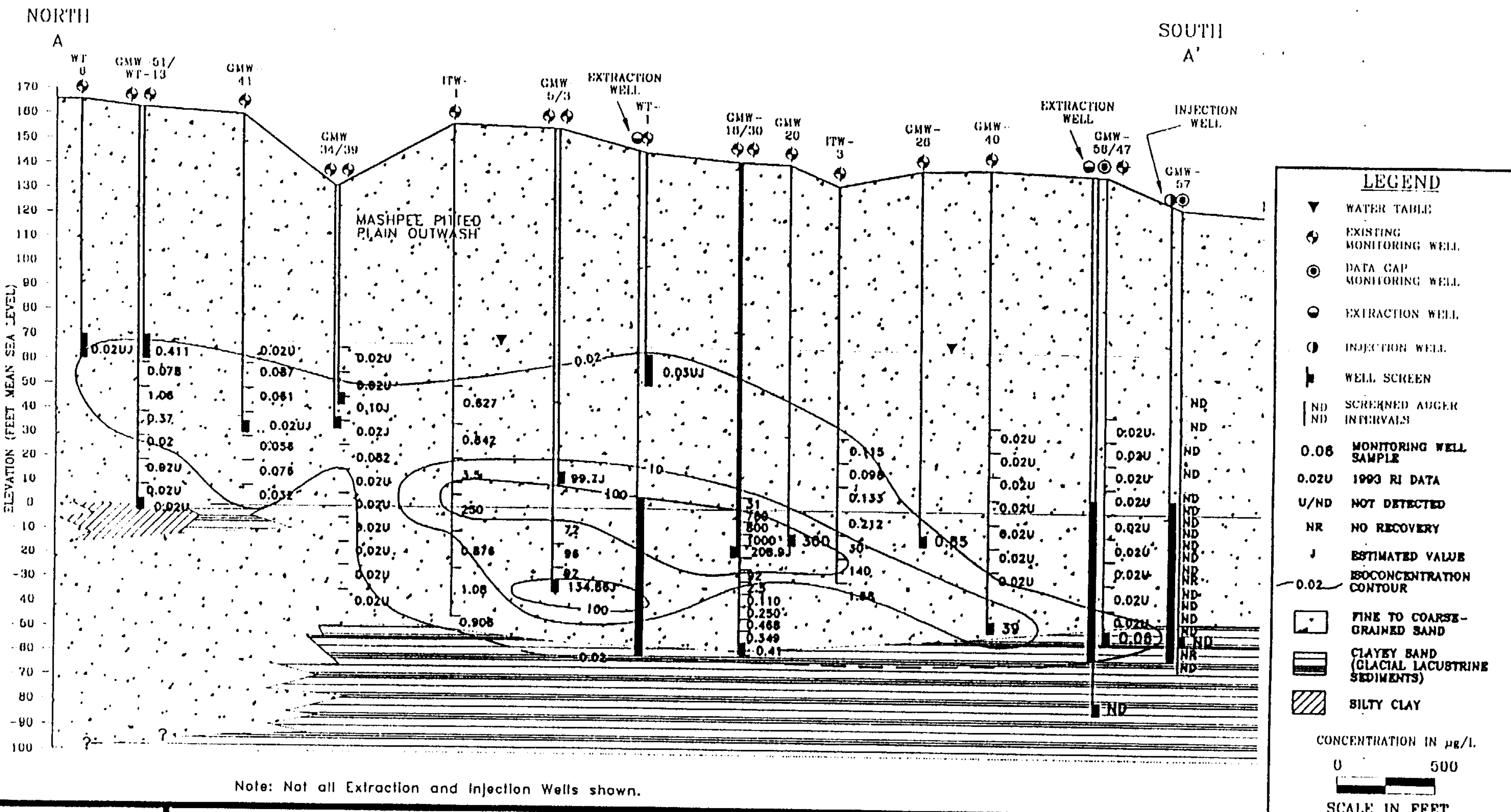
2.4.3 Screen Locations

Recommended screen depths for the extraction and reinjection well network are shown in Table 2-1. Figures 2-4 and 2-5 provide cross sectional views of screen depths for select extraction and reinjection wells. Recommended screen depth intervals for all extraction wells in this Draft Design Report are from 5 feet above mean sea level (msl) to 60 feet below msl. This screen depth was selected to include the section of maximum plume contamination in the axial extraction well

fence and the maximum depth of plume contamination along the southern boundary of the FS-12 plume. Based on groundwater modeling efforts, the proposed extraction well screen depths are capable of capturing the entire extent of groundwater contamination above MCLs at FS-12 with the exception of two areas, the extreme eastern portion of the 0.02 ppb EDB contour and the extreme southwestern portion of the 0.02 EDB contour along Snake Pond. However, since the EDB plume boundary above MCLs in these areas is uncertain, additional data collection activities will be conducted prior to construction of the FS-12 ETR system to verify the plume dimensions. Following data collection and review, design refinements will be made if necessary.

Recommended screen depths for reinjection wells range from 30 feet above msl to 30 feet below msl for the western reinjection well fence and from 5 feet above msl to 60 feet below msl for the southern reinjection well fence. Based on groundwater water modeling efforts, the proposed depth of the western reinjection well fence was selected to minimize circulation of reinjected water to the extraction well fence and to enhance plume capture. The proposed depth of the southern reinjection well fence was selected to minimize impact to the J. Braden Thompson Plume.

As described in Section 2.5.1, additional data collection activities will be conducted prior to construction of the FS-12 ETR system. This data will include groundwater screening and lithology information to better define appropriate screen intervals for extraction and reinjection wells.



Note: Not all Extraction and Injection Wells shown.

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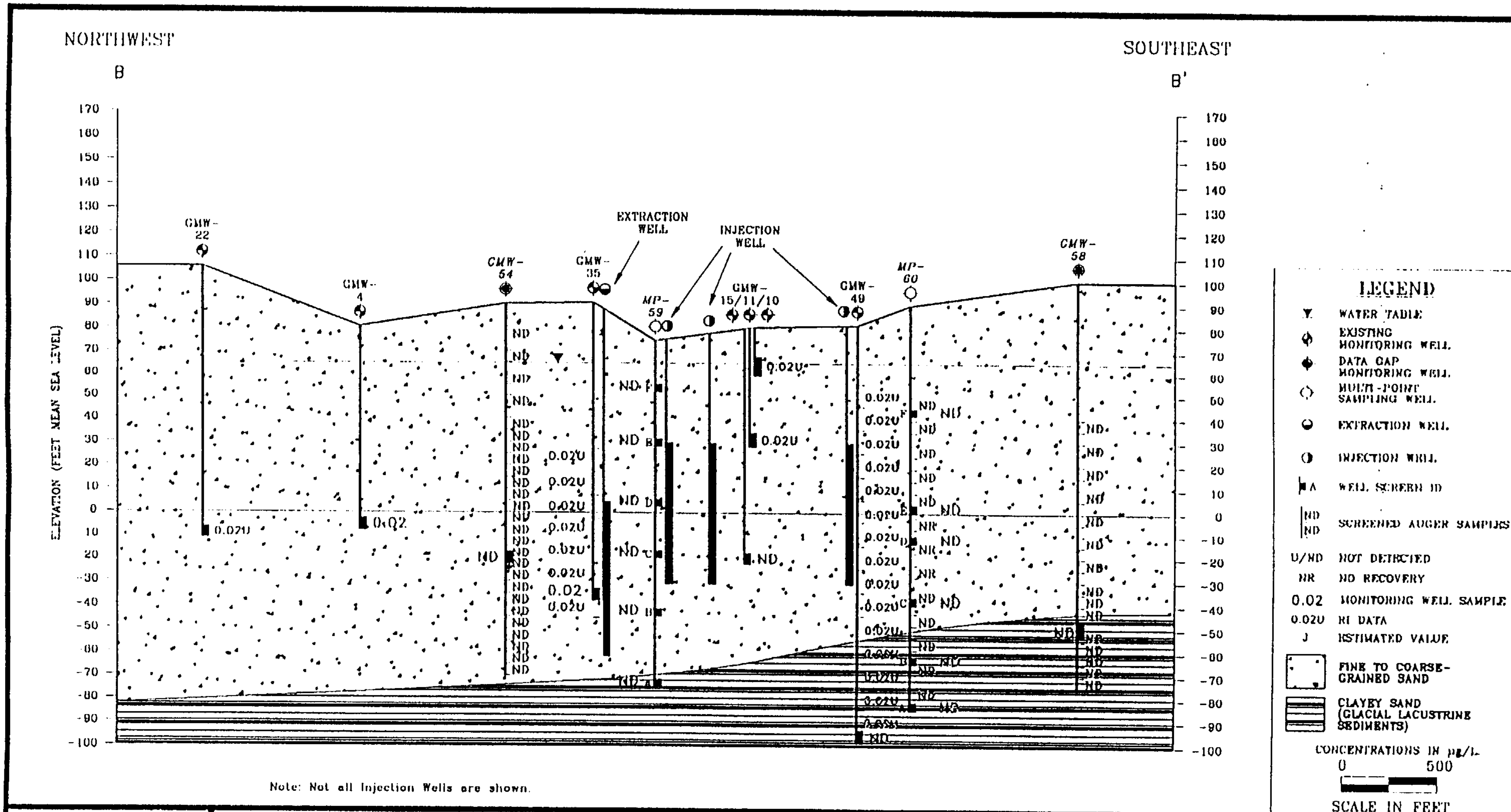
REFERENCED FROM OPTECH

EDB ISOCONCENTRATION
CROSS-SECTION A-A' AT FUEL SPILL-12
Massachusetts Military Reservation
Cape Cod, Massachusetts

DRAFT
FIGURE 2-4

OTIS\JMODELG\FS-12_A



JE JACOBS ENGINEERING

Referenced from OPTECH

EDB ISOCONCENTRATION
CROSS-SECTION B-B' AT FUEL SPILL-12
Massachusetts Military Reservation
Cape Cod, Massachusetts

DRAFT
FIGURE 2-5

OTIS\JMODRLG\FS-12_B

2.4.4 Pumping and Reinjection Rates

Recommended pumping and reinjection rates were iteratively selected by performing groundwater modeling and particle tracking simulations. As described in Section 2.4.1, Summary of Modeling Efforts For FS-12, fifteen different well network configurations were tested before recommending Scenario 15. The pumping and reinjection rates recommended in Table 2-1 achieved a satisfactory balance between stakeholder objectives. Based on the modeling results, the recommended extraction well pumping rates will produce less than 0.5 feet of drawdown at a distance of 50 feet from the extraction wells while still maintaining capture of the groundwater plume. Drawdown at distances greater than 50 feet from the extraction wells will be minimal. Recommended injection rates for reinjection wells are projected to have even less impact on groundwater elevations at FS-12. Groundwater modeling results indicate that at a distance of 50 feet from the reinjection wells, less than 0.3 feet of mounding will occur at the recommended reinjection well injection rates. Mounding at distances greater than 50 feet will be minimal. The anticipated changes in groundwater elevations at FS-12 from the proposed FS-12 ETR system are much less than seasonal variations in groundwater elevations measured at MMR.

2.4.5 Modeling Uncertainties

Groundwater modeling was utilized as one of the primary tools in developing the proposed FS-12 ETR system. However, it is important to recognize that all modeling efforts contain uncertainty. The Plume Containment Design Groundwater Modeling Report (OpTech 1996b) outlines many of the primary uncertainties in groundwater modeling. By performing additional data collection activities prior to construction and providing considerable flexibility in the operating flow and influent water quality range that the FS-12 ETR system can handle, it is anticipated that design uncertainties can be managed effectively.

2.4.6 Additional Modeling Efforts

Jacobs is currently working with stakeholders to address comments on previous groundwater modeling efforts. In addition, as data becomes available the groundwater model for FS-12 will be updated. Following completion of data collection activities and incorporation of stakeholders comments, Jacobs will present the results of the final groundwater modeling simulations, including recommendations for any design refinements, if required for review and approval by all stakeholders.

2.5 DATA COLLECTION ACTIVITIES

To compensate for potential design uncertainties, the design approach includes additional data collection efforts before and during the initial construction period. These efforts are described in this section.

2.5.1 Preconstruction Plume Definition Data Collection

As discussed in the Draft FS-12 Plume Containment System Project Execution Plan (Jacobs 1996), two screened auger borings will be planned to be advanced near the east-central portion of the plume to provide verification of the estimated upper bounds of the plume. See Figure 2-6 GW Screening & Lithology numbers GWM 59 and GWM 61. Installation of wells at these locations was intended to provide the following specific information:

- To assess contaminant distribution at approximately 20-40 feet above mean sea level (msl) in the vicinity of existing well GMW-20.
- To assess the potential presence of contaminants at approximately 5 to 20 feet above msl in the area between wells GMW-32/GMW-44 and GMW-33.

Based on screening data obtained at the two boring locations it was determined that a deep well (installed at approximately 174 to 179 feet below ground surface

(bgs) was necessary to create a nested pair at the location of MW-20. This well was required to delineate the lower limits of EDB contamination detected during groundwater screening.

As a result of resolution reached at the FS-12 groundwater design basis meeting conducted on September 30, 1996, three additional "data gap" groundwater screening locations were identified as critical to the understanding of in-plume contaminant distribution. Groundwater screening using screened hollow stem auger (or alternative method, e.g., Hydropunch) will be conducted at the following three locations:

1) It was determined that additional groundwater data southeast of well GWM-4 was necessary to verify the magnitude and vertical extent of the western portion of the plume (Figure 2-6) GWM-64. The interpolated dimension of the western portion of the plume has been based on data collected from one well (GMW-4). Groundwater screening samples will be collected on ten-foot intervals from the water table to depth of approximately 140 feet below the water table. This interval sufficiently straddles the anticipated plume depth; however, if contamination is detected near the proposed bottom, screening boring samples will be collected until at least two vertically-adjacent screening intervals are free of contaminants.

2) It was determined that a groundwater screening boring was necessary immediately south of the FS-12 source area to better delineate the vertical extent of the plume and to identify contaminant magnitude (Figure 2-6) GWM-62. This boring location is situated south-southwest of existing well WT13. Groundwater samples will be collected on ten foot intervals from the water table to a depth of approximately 120 feet below the water table. This interval straddles the anticipated plume vertical limits. However, if contamination is detected at the bottom of the boring, samples will be

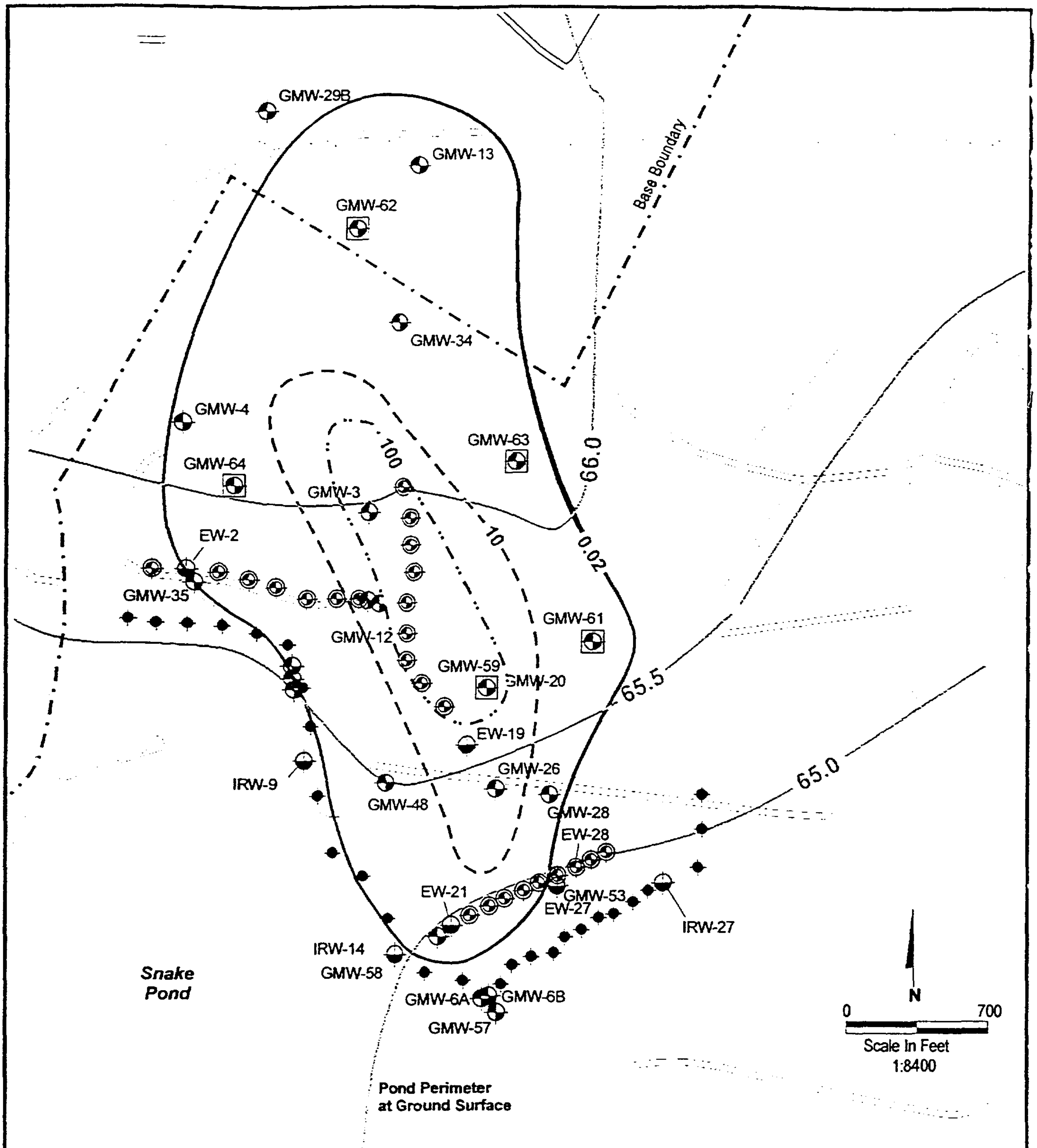
collected until at least two vertically-adjacent samples are free of contaminants.

3) It was determined that a groundwater screening boring is necessary to evaluate the magnitude and extent of contamination in the northeastern portion of the plume east-northeast of well GMW-3 (Figure 2-6) GWM-63. To date, the eastern limits of the plume have been based on data collected from wells GMW-33 and GMW-36 which are situated more than 1800 feet apart. More importantly, there are no wells crossgradient (in an easterly direction) of the most contaminated portion of the plume. Groundwater samples will be collected on ten-foot intervals from the water table to approximately 140 feet below the water table. This interval straddles the anticipated limits of the plume. However, if contamination is detected at the bottom of the boring, samples will be collected until at least two vertically-adjacent samples are free of contaminants.

The Execution Plan proposed a "Pilot Boring Plan" to collect groundwater screening and lithologic data at select extraction and injection well sites wells. This data was proposed to be collected during the installation of these wells. It is now proposed that this data be collected during the preconstruction data collection program. Table 2-2 outlines the planned sampling activities. Groundwater screening sampling and soil sampling for lithologic characterization (stratigraphic correlation) will be conducted at several extraction and reinjection wells distributed across the ETR fence area. This data will be used to further delineate the extent of the plume at the source area extraction wells and at the western and southern containment portions of the fence.

Groundwater samples and soil lithologic sampling will be conducted on ten foot intervals from extraction wells EW-2, EW-14, EW-19, EW-21, EW-27, and reinjection wells IRW-9, IRW-14, and IRW-27 as shown in Figure 2-6.

The proposed depth of groundwater screening sampling and soil sampling is detailed in Table 2-2. It may be possible to collect the soil and groundwater samples from the same borehole at alternating ten-foot intervals using rotosonic drilling and Hydropunch sampling techniques. If both soil and groundwater samples cannot be collected from the same borehole, the borings for groundwater screening and lithologic sampling will be installed immediately adjacent to one another.



Sample Existing GW Monitoring Well

Extraction Well

Reinjection Well

GW Screening & Lithology (Extraction & Injection)

GW Screening & Lithology (New Monitor Well)

Line of Equal Groundwater Contamination

Isoconcentration Contour Line of EDB (concentration in µg/L)

0.02

10

100

Maximum contaminant level for EDB=0.02 µg/L (Massachusetts MCL)

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FUEL SPILL 12
PRECONSTRUCTION
SAMPLING LOCATIONS

Massachusetts Military Reservation
Cape Cod, Massachusetts

10/10/96 Drawn By: KK File:..edbfs12b.cdr

Figure 2-6

TABLE 2-2
FS-12 GROUNDWATER SCREENING AND SOIL SAMPLING AT PROPOSED WELL LOCATIONS

WELL IDENTIFICATION [1]	DEPTHS OF GW SCREENING (GW) AND SOIL SAMPLING FOR VISUAL SOIL CLASSIFICATION (SOIL) [2,3]	SOIL SAMPLE INTERVALS FOR GRAIN SIZE ANALYSIS [4]	NUMBER OF SAMPLES AND LOCATIONS
REINJECTION WELLS			
IRW-9	GW - 20' below water table (BWT) to 140' BWT SOIL - 20' BWT to 140' BWT	30 ft mean sea level (msl) to -30 ft msl (Approximately 35' BWT to 95' BWT)	3 samples total Top, middle, & bottom of screen
IRW-14	GW - 20' BWT to 140' BWT SOIL - 20' BWT to 140' BWT	30 ft msl to -30 ft msl (Approximately 35' BWT to 95' BWT)	3 samples total Top, middle, & bottom of screen
IRW-27	GW - 40' BWT to 140' BWT SOIL - 40' BWT to 140' BWT	5 ft msl to -60 ft msl (Approximately 65' BWT to130' BWT)	3 samples total Top, middle, & bottom of screen
EXTRACTION WELLS			
EW-2	GW - WT to 140' BWT SOIL - 30' BWT to silty sand (~140' BWT)	5 ft msl to -60 ft msl (Approximately 65' BWT to 130' BWT)	3 samples total Top, middle, & bottom of screen
EW-14	GW - WT to 140' BWT SOIL - 50' BWT to clayey sand (~140' BWT)	5 ft msl to -60 ft msl (Approximately 65' BWT to130' BWT)	3 samples total Top, middle, & bottom of screen
EW-19	GW - 40' BWT to 140' BWT SOIL - 50' BWT to clayey sand (~140' BWT)	5 ft msl to -60 ft msl (Approximately 65' BWT to130' BWT)	3 samples total Top, middle, & bottom of screen
EW-21	GW - 40' BWT to 140' BWT SOIL - 50' BWT to clayey sand (~140' BWT)	5 ft msl to -60 ft msl (Approximately 65' BWT to130' BWT)	3 samples total Top, middle, & bottom of screen
EW-27	GW - 40' BWT to 140' BWT SOIL - 50' BWT to clayey sand (~140' BWT)	5 ft msl to -60 ft msl (Approximately 65' BWT to130' BWT)	3 samples total Top, middle, & bottom of screen

TABLE 2-2
FS-12 GROUNDWATER SCREENING AND SOIL SAMPLING AT PROPOSED WELL LOCATIONS

WELL IDENTIFICATION [1]	DEPTHS OF GW SCREENING (GW) AND SOIL SAMPLING FOR VISUAL SOIL CLASSIFICATION (SOIL) [2, 3]	SOIL SAMPLE INTERVALS FOR GRAIN SIZE ANALYSIS [4]	NUMBER OF SAMPLES AND LOCATIONS
PRECONSTRUCTION DATA GAP GW SCREENING/MONITORING WELLS			
GMW-59 (Near MW-20)	GW - WT to 130' BWT	none	N/A
GMW-61 (Near MW-44/32, 33)	GW - WT to 130' BWT	none	N/A
GMW-62	GW - WT to 120' BWT SOIL - WT to silty sand (~140' BWT)	none	N/A
GMW-63	GW - WT to 140' BWT SOIL - WT to silty sand (~140' BWT)	none	N/A
GMW-64	GW - WT to 140' BWT SOIL - WT to silty sand (~140' BWT)	none	N/A

1 See Figure 2-6 for well/groundwater screening locations.
2 Soil samples are for visual soil classification and stratigraphic correlation.
3 Groundwater and soil samples will be collected over alternating 10 foot intervals (first 5 ft for GW sample, next 5 ft for soil sample).
4 Grain size analysis to be conducted to determine screen slot size and sand pack requirements.

If groundwater screening results do not agree with the anticipated plume dimensions the need to modify the design (well screen intervals and pumping rates) will be assessed and evaluated in consultation with stakeholders. Any suggested modifications will be submitted for review and approval.

During the preconstruction data collection program three soil samples from each of the aforementioned extraction and reinjection wells will be collected and submitted for grain size analysis and hydraulic conductivity. This data will be used to appropriately size the well screen and well screen sand pack. These samples will be collected at depths corresponding to the top, middle, and bottom of the screen interval (see Table 2-2).

2.5.2 Baseline Sampling

As part of the Preconstruction Data Collection Program a limited baseline groundwater sampling event will be conducted. Select wells will be sampled to verify plume delineation. The selected wells are situated throughout the plume at locations near the toe of the plume, near the center of the plume and at the source area. The wells proposed for the baseline sampling are presented in Table 2-3. It should be noted that an additional more comprehensive "baseline" groundwater sampling event will also occur immediately prior to system operation (during the initial phase of system start-up). This sampling event will be discussed in greater detail in the Performance Monitoring Evaluation Plan. If the baseline Preconstruction sampling results do not agree with the anticipated plume dimensions the need to modify the design will be assessed and evaluated in consultation with stakeholders. Any suggested modifications will be submitted for review and approval.

TABLE 2-3
FS-12 EXISTING WELL BASELINE SAMPLING

	CONTAMINANTS ANALYZED	
WELL ID	VOCs	EDB
GMW-3	X	X
GMW-4	X	X
GMW-12	X	X
WT-13	X	X
GMW-20	X	X
GMW-26	X	X
GMW-28	X	X
GMW-29B	X	X
GMW-34	X	X
GMW-35	X	X
GMW-48	X	X
GMW-53	X	X
GMW-57	X	X
GMW-58	X	X

2.5.3 Geotechnical Analysis

A geotechnical analysis will be performed in the area of the proposed FS-12 Treatment Plant to ensure the soils at the proposed location have an appropriate bearing capacity for the foundations and equipment specified.

2.5.4 Hydraulic Data Collection

The design of the ETR fence has been based in part on slug test and pump test data collected in the vicinity of the FS-12 plume. This information was also used as input to the groundwater flow model. During the development of this design package a groundwater extraction and reinjection pilot test was conducted northwest of Snake Pond. Preliminary data has been provided to Jacobs and is currently being evaluated. This data will be used to verify assumed hydraulic parameters and to assess the groundwater model predicted responses to extraction and reinjection stresses. Based on preliminary evaluation of the pumping/reinjection test data it appears that the hydraulic conductivity in the vicinity of the test location ranges from approximately 300 to 550 feet per day. This hydraulic conductivity range is slightly greater than the assumed value applied in the model but is not significantly different than data collected from other aquifer pumping tests in the outwash deposits in the vicinity of FS-12. It is not anticipated that additional long-duration constant-rate pumping tests will be required. However, additional step-rate tests will be conducted at select extraction and injection well locations during construction (see Data Collection During Construction, below). The significance of the constant rate aquifer pumping test data collected at FS-12 as related to the need to refine the model is being assessed. Following analysis of the pumping test data, the groundwater model will be revised, if necessary. Reevaluation of the design flow rates and well spacing will be conducted to determine if modifications are necessary. Field conditions (i.e., drawdown) will again be compared with model simulations, if necessary to confirm predictions of the recalibrated model. Following

recalibration, a refined pumping scenario will be developed and implemented. If necessary, additional model simulations may be performed to recalibrate the model and further refine pumping rates.

2.5.5 Ecological Data Collection

Based on the groundwater modeling performed during evaluation of the FS-12 ETR system, system operations may have an impact on Snake Pond. Model results suggest that groundwater mounding (less than 0.3 feet) may occur in the vicinity of the eastern edge of the Pond. In addition the model predicts that approximately 30 percent of the total groundwater flux entering Snake Pond may be inflow in water from the FS-12 ETR system.

The following paragraphs provide a preliminary estimate of the potential changes in water quality that might occur in Snake Pond as a result of mixing ambient groundwater and reinjected effluent from the FS-12 plume extraction/ treatment/ reinjection (ETR) system. This estimate is intended to provide a rough order of magnitude approximation as a basis for identifying parameters where more detailed evaluation is necessary. Potential changes were based on the following assumptions:

- No chemical or physical changes occur in the reinjected effluent between the point of recharge and Snake Pond.
- Mixing effects and spatial variations within the Pond itself are not considered.
- Chemical interactions between constituents of the reinjected water and pond water are neglected.
- Average annual values for rainfall and groundwater recharge are used in estimating flow rates.

Based on the groundwater modeling performed during evaluation of the FS-12 ETR System, Snake Pond receives approximately 0.23 million gallons per day (MGD) from rainfall on an annual basis, and approximately 1.09 MGD recharge from subsurface groundwater. The total average inflow to Snake Pond on an annual basis is therefore approximately 1.3 MGD.

The model results also suggest that approximately 0.4 MGD of reinjected water would enter Snake Pond after the ETR system is operational. Thus, the future inflow to the pond would be comprised of approximately 17% rainfall (0.23 MGD), 53% ambient groundwater (0.69 MGD), and 30% reinjected effluent (0.40 MGD). Neglecting mixing effects in the pond itself and changes in quality as the reinjected water travels through the aquifer before reaching Snake Pond, the resulting chemical quality of the pond water would be approximately equal to the flow-weighted average of the individual components. If, for example, a particular compound was completely removed by the treatment process, the concentration of that compound in Snake Pond would be expected to decrease by approximately 30%. For any given parameter, the future concentration in Snake Pond water would be approximated by the following relationship:

(Concentration after FS-12 ETR is operational)=0.7 (ambient concentration)
+0.3 (concentration in treated effluent)

Because the influent water will be heated as it undergoes unit operations, the treatment plant effluent will be approximately 2.2°F warmer, on average, than the influent (ambient groundwater). Based on 30% of the recharge water into Snake Pond being effluent, pond recharge water will be approximately 0.7°F warmer once the ETR system is fully operational and the hydrogeologic system reaches equilibrium. Heating the aquifer matrix along the flow path will take many years; thus, the increase in temperature will be gradual.

The pH of the treatment plan effluent will be near neutral (pH 7), and will be somewhat higher than the slightly acidic ambient groundwater (5.2-6.5). Although it is difficult to determine the pH change that will occur in the reinjected groundwater because of dilution and natural buffers, the change should certainly be less than 1 pH unit.

Nitrogen (in the form of ammonia, nitrates, and nitrites) will not be significantly removed by the treatment plant unit operations. Likewise, dissolved inorganic anion-, inorganic carbon- and phosphate concentrations will not be substantially reduced during treatment. Thus, no significant changes in Snake Pond are anticipated for these compounds.

TOC in extracted groundwater will be almost entirely removed by the activated carbon. TOC contributed to the pond would thus decrease, but the amount of the decrease cannot be predicted as the biologic activity within the pond dominates the concentration of this component.

There will likely be changes in other chemical parameters, including dissolved oxygen (DO), total suspended solids (TSS) and total dissolved solids (TDS). Assuming an average DO of 10 mg/L in ambient groundwater, DO in recharge will decrease by approximately 3 mg/L. Redox potential won't change unless the DO drops below 0.5 mg/L. TSS in recharge water will also be reduced by up to 9%, as treatment plant filters will remove the majority of solids. Iron and manganese should be nearly completely removed.

Because the treatment system would have minimal or no impact on the following parameters, their concentrations in Snake Pond should be unaffected by ETR operations:

- Inorganic ions (other than sodium used in pH control).
- Ammonia.

- Hardness
- Dissolved Inorganic Carbon.
- Soluble Reactive Phosphate.

These estimates are based on an ambient groundwater flow of approximately 1.3 MGD. The USGS has estimated independently that water through Snake Pond is approximately 0.6 MGD. In that case, the potential changes in Snake Pond water quality as described above would be increased proportionally.

Ecological sampling has been initiated at Snake Pond and other ponds, wetlands, and ecologically sensitive areas of the site to obtain baseline data that can be used in assessing the potential impacts of changes in the ambient pond conditions. Efforts to develop facility-wide and FS-12 specific ecological sampling programs are currently underway. An Ecological TRET meeting was conducted on October 9 and 10, 1996 to establish the conceptual framework (and some specific data collection techniques) for the ecological studies. It is likely that the ecological sampling plan for FS-12 will provide data to subsequently conduct a focused assessment of the potential hydraulic impact of the FS-12 ETR system on Snake Pond and the assessment of the potential impact of "treated water" on the pond ecosystem. The scope of the ecological investigation will be presented in the aforementioned sampling program plan.

Based on the results of that assessment and operational monitoring, it may be necessary to slightly modify the FS-12 ETR network in the future to limit hydraulic impact on the Pond and/or to modify the treatment process to return reinjected water with some of the constituents at concentrations closer to ambient (untreated) conditions. As a minimum, the system will be started slowly to allow monitoring any impact on the pond.

2.5.6 Data Collection During Construction

Following the Preconstruction Data Collection Program (and system refinement, if required based on the data discussed above) a step-drawdown test will be conducted at three extraction well locations (EW-3, EW-17, and EW-25) and step-drawdown and step-injection tests will be conducted at three injection well locations (IRW-6, IRW-14 and IRW-26) to assess specific capacity, well performance and provide verification of presumed aquifer hydraulic conductivity.

2.6 REGULATORY REQUIREMENTS

2.6.1 Introduction

This section identifies and discusses federal, state, and local environmental applicable or relevant and appropriate requirements (ARARs) for the MMR FS-12 plume response project, plus discusses other regulatory requirements such as compliance with the Record of Decisions (ROD) or recommendations from the Technical Review and Evaluation Team (TRET).

2.6.2 Applicable Or Relevant And Appropriate Requirements (ARARS)

Project Scope

The project includes the installation of groundwater extraction wells, the installation of collection systems for the extracted groundwater, the installation of groundwater treatment systems, the installation of treated water distribution systems, the installation of groundwater reinjection wells, and the installation of groundwater monitoring wells. The project also includes operation and maintenance of the extraction, treatment, and reinjection system. The following elements of the project work were considered in determining the appropriate ARARs:

- Construction of decontamination facilities.

- The placement of support facilities.
- Access road improvement.
- Tree clearing, grubbing, and topsoil stripping.
- Extraction, monitoring well, and reinjection well installation and operation.
- Air emissions.
- Residuals management.
- Potable water supplies to the treatment units.
- Septic Systems.

The Federal and State ARARs pertinent to these elements are summarized in Table 2-4.

Federal ARARs

The following federal environmental statutes have been identified as potential ARARs for the installation and operation of the FS-12 plume response project:

- Clean Air Act (CAA)
- Clean Water Act (CWA)
- Safe Drinking Water Act (SDWA)
- Resource Conservation and Recovery Act (RCRA)

The following sections discuss these regulations and their pertinence to the FS-12 project.

Clean Air Act

The objective of the CAA is to protect and enhance the quality of the nation's air resources in order to promote and maintain public health and welfare and the nation's production capacity. The programs within the CAA that contain potential ARARs for the FS-12 project are the National Ambient Air Quality

Standards (NAAQS) for Criteria Pollutants, and the National Emission Standards for Hazardous Air Pollutants (NESHAP).

NAAQS for six pollutants (carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone, and sulfur oxides) appear in the Code of Federal Regulations (CFR) in 40 CFR 50. These standards are based on the direct health effects of these pollutants to sensitive groups, with no consideration to economic factors. The NAAQS take all sources of a given pollutant into account and establish ceilings that are not to be exceeded in the United States. The only FS-12 Plume Response project activities that could impact NAAQS is volatile organic carbon emissions (VOCs) that can contribute to ozone formation. The ceiling for ozone is relevant and appropriate to these activities.

In general, new sources of air emissions must undergo a pre-construction review. Preconstruction reviews are conducted to determine whether a new source will interfere with attainment or maintenance of NAAQS. The permitting process associated with attainment of NAAQS applies only to major sources of air emissions. The FS-12 plume containment project will not be a major source of air emissions, and the concentration of VOCs in the groundwater plumes are very low (micrograms/liter range). However, compliance with NAAQs is an ARAR for the plume containment projects.

A number of compounds have been detected in the FS-12 groundwater plume that are included in the list of hazardous air pollutants (HAPs). In addition, benzene was detected in the plume, which is on the list of NESHAP compounds. In general, the NESHAP regulations give emission limits for hazardous air pollutants and mandate testing, monitoring, and reporting requirements. The HAP and NESHAP compounds are only present in the groundwater plumes in low, (micrograms/liter) concentrations and are not expected to generate significant air emissions. However, meeting the requirements of NESHAPs is an ARAR for the plume containment projects.

Clean Water Act

The primary purpose of the CWA, also known as the Federal Water Pollution Control Act, is to restore and maintain the quality of surface waters.

The CWA is applicable to the disposal of liquid residuals. The contaminated groundwater will be extracted, treated, and reinjected. Since reinjected groundwater can potentially reach surface waters, the requirements of the CWA will be ARARs. The CWA may impose limitations, standards and permit conditions. The CWA will also impose standards for stormwater runoff during construction and from the treatment systems.

Safe Drinking Water Act

The purpose of the SDWA is to protect and maintain Unites States drinking water resources. This regulation is an ARAR for the reinjection of treated groundwater and for the handling of treatment area residuals, such as backwash from the removal of suspended solids and iron. The SDWA specifies maximum contaminant levels (MCLs) and MCL goals for inorganic and organic chemicals and microbiological contaminants.

Resource Conservation and Recovery Act

RCRA is applicable to the solid treatment residuals. Solid treatment residuals include: drill cuttings from the installation of wells, spent activated carbon, and sludges from the removal of suspended solids and iron. The drill cuttings and sludges are expected to pass the Toxicity Characteristic Leaching Procedure (TCLP) and are not expected to require handling and disposal as a hazardous waste. The activated carbon may not pass the TCLP test and may need to be handled and regenerated as a hazardous waste.

State ARARs (Commonwealth Of Massachusetts)

The Commonwealth of Massachusetts ARARs identified as pertinent to the FS-12 plume response project include:

- 302 CMR 6: Adopting Inland Wetland Orders
- 310 CMR 6: Ambient Air Quality Standards for the Commonwealth of Massachusetts
- 310 CMR 7: Air Pollution Control
- 310 CMR 15: The State Environmental Code, Title 5, Standard Requirements for the Siting, Construction, Inspection, Upgrade and Expansion of On-Site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage.
- 310 CMR 19: Solid Waste Management
- 310 CMR 22: Drinking Water Regulations
- 310 CMR 27: Underground Water Source Protection
- 310 CMR 30: Hazardous Waste
- 310 CMR 40: Massachusetts Contingency Plan
- 314 CMR 2: Permit Procedures
- 314 CMR 5: Groundwater Discharge Permit Program
- 314 CMR 6: Groundwater Quality Standards
- 314 CMR 8: Supplemental Requirements for Hazardous Waste Management Facilities
- 314 CMR 12: Operation and Maintenance and Pretreatment Standards for Wastewater Treatment
- 314 CMR 15: The Prevention and Control of Oil Pollution in the Waters of the Commonwealth

302 CMR 6: Adopting Inland Wetland Orders

The intent of this regulation is to "preserve and promote the public safety, private property, wildlife, fisheries, water resources, flood plain areas and agriculture, and to prevent damage to the environment". These goals are to accomplished by imposing restrictions on the inland wetlands and flood plain areas.

If any of the activities associated with the FS-12 plume response project impact wetlands or flood plains, which is not anticipated, then this section will become an ARAR.

310 CMR 6: Ambient Air Quality Standards for the Commonwealth of Massachusetts

This chapter sets ambient air quality standards for: sulfur dioxide, particulates, carbon monoxide, ozone, nitrogen oxides, and lead. NOTE: These regulations are essentially the same as the federal regulations included as part of the Clean Air Act.

310 CMR 7: Air Pollution Control

Section 7.02 defines the types of facilities which are required to file Environmental Notification Forms (ENF). No substantial construction or reconstruction is allowed unless any required ENF is filed and approved. Exemptions to this requirement are listed in subsection (4)(a). The FS-12 plume response project is probably excepted by subsection (4)(a)8, emission less than one ton/year.

Section 7.03 provides additional exemptions to the permitting requirements. Subsection (14) provides an exemption for groundwater remediation and soil venting projects, as long as treatment systems are provided that achieve at least a 95% reduction in VOC emissions. The groundwater concentrations are very low so significant air emissions are unlikely. However if air emissions become significant the 95% reduction requirement may become and ARAR. An additional exemption is provided by 314 CMR 0049 which allows for a waiver

from the 95% control requirement if it can be demonstrated that the air emission will present no significant risk to public health.

Section 7.18 provides additional restrictions for emissions from volatile or halogenated organic compounds. However, this section is not applicable because it is restricted to specific, listed processes. None of the processes listed include groundwater remediation projects.

310 CMR 15: The State Environmental Code, Title 5: Standard Requirements for the Siting, Construction, Inspection, Upgrade and Expansion of On-site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage

Section 15.003 specifies that a construction permit is required for installation of any septage system, except for systems operated by an agency of the Commonwealth or of the Federal Government.

Section 15.260 provides design information for "Tight Tanks", if used.

310 CMR 19: Solid Waste Management

This chapter provides the requirements for solid waste facilities. This chapter is not applicable for the FS-12 plume response project.

310 CMR 22: Drinking Water Regulations

Chapters 22.05 through 22.11 list the maximum allowable concentrations of contaminants in drinking water and requires that certified labs be used to conduct the sample analysis.

310 CMR 27: Underground Water Source Protection

Section 27.03 lists the Classes of reinjection wells. The reinjection wells used as part of the FS-12 plume response project will be Class V wells, wells not included as types I through IV.

Section 27.04 lists that Class V wells are not allowed if they will move pollutants to underground drinking water supplies.

310 CMR 30: Hazardous Waste

Section 30.102 lists the methods for the identification of hazardous waste.

Section 30.104 lists wastes that are exempt from the hazardous waste regulations. Samples collected for testing are exempt from the regulations.

Section 30.125 describes the EP Toxicity test to determine if a waste is a characteristic hazardous waste.

Section 30.141 describes when a hazardous waste becomes hazardous and states that a characteristic hazardous waste ceases to be hazardous when it no longer exhibits the characteristics of a hazardous waste.

Section 30.354 lists general requirements for hazardous waste treatment, storage, and disposal facilities. The FS-12 plume response facilities will not be TSD facilities, but for protection of the public it may be appropriate to design parts of the facilities to meet TSD requirements.

Section 30.402 lists the requirements for the transport of hazardous waste. Spent carbon from the treatment systems may be an EP Toxicity hazardous waste and may need to meet the requirements of this section.

Section 30.693 lists design and installation requirements for hazardous waste tank systems. The FS-12 plume response system will not be a hazardous waste system, but for protection of the public it may be appropriate to design portions of the treatment systems to meet the requirements of this section.

Section 30.694 lists requirements for the containment of leaks from hazardous waste facilities. It may also be appropriate to design portions of the treatment system to meet these requirements.

Section 30.695, 30.696, and 30.697 list operating, inspection, and response requirements to prevent or control leaks and spills from hazardous waste facilities. It may also be appropriate to meet portions of these requirements.

310 CMR 40: Massachusetts Contingency Plan

Section 40.0041 states that no discharge to surface water or to groundwater is allowed except as provided by Chapter 40. This section also states that any water discharged within 200 feet of "Outstanding Resource" water is not allowed unless the discharged water meets groundwater quality standards and that a permit is required for discharge to the groundwater. Meeting the requirements for a groundwater permit will be an ARAR for the FS-12 plume response project.

Section 40.0045 lists the following requirements for the discharge of remediation effluent to the groundwater:

- The discharge must not impair the quality of the groundwater - the discharge must meet the concentration requirements listed in 314 CMR 6.0.
- The discharge must not create groundwater mounding within two feet of the surface.
- The discharge must not result in flooding or breakout to the ground surface.
- The discharge must not exacerbate existing conditions or impair the remediation of existing conditions.

Section 40.0049 states that air emissions from remediation activities can be exempted from the 95% control requirement if it is demonstrated that the emissions presents no significant risk to public health.

Sections 40.0855 and 40.0857 discuss the identification of remedial alternates and the evaluation of those alternates. These sections state that a detailed evaluation of alternates is not required as long as the selected alternate results in destruction

or detoxification of the material, can be implemented without a significant risk or harm to the health, safety, public welfare, or the environment.

Section 40.0874 lists the contents of a Remedial Implementation Plan (RIP). The intent of this plan is being satisfied by submittal of this document.

Section 40.0890 lists requirements for operation and maintenance of the remedial action. This section requires monitoring to make sure the remediation specifications are met, requires correction of any problems that are discovered, and requires documentation of compliance.

314 CMR 2: Permit Procedures

Section 2.01 states that discharges to groundwater be permitted per Section 2.05.

Section 2.03 lists the required permit forms for discharges to groundwater.

Section 2.05 lists the contents of a "Fact Sheet" used as a basis for the permit.

314 CMR 5: Groundwater Discharge Permit Program

Section 5.03 states that anyone who discharges onto or below the land surface is required to file a permit application. The requirements of this permit application will be an ARAR for the FS-12 plume response project.

Section 5.04 states that the groundwater discharge permit include any stormwater that has come into contact with process wastes. The contact between stormwater and the process wastes will not occur as part of these projects, but demonstration that no contact will occur can be a project ARAR.

Section 5.10 lists effluent concentration limitations. Maximum concentrations are set for a number contaminants which may be present in the extracted groundwater including: lead, iron, manganese, total dissolved solids, pH, nitrate, and total nitrogen. In addition, the concentration of any toxins must meet "Health Advisory Levels".

Section 5.19 lists the following requirements for discharge to the groundwater:

- No discharge can result in a violation of surface water or groundwater quality standards.
- The discharge must meet the requirements of 40CFR307(a)
- Bypass of the treatment system is prohibited.

Section 5.26 contains a form for applying for a permit to discharge industrial waste to the groundwater.

314 CMR 6: Groundwater Quality Standards

Section 6.06 lists minimum groundwater quality standards.

Section 6.07 states that no discharge will occur to the groundwater without a permit.

314 CMR 8: Supplemental Requirements for Hazardous Waste Management Facilities

Section 8.01 states that wastewater treatment units which treat, store, or dispose of hazardous waste generated at the site must comply with 310 CMR 30. The spent carbon generated at the FS-12 treatment system may be a hazardous waste based on the EP Toxicity criteria.

314 CMR 12: Operation and Maintenance and Pretreatment Standards for Wastewater Treatment

Section 12.03 states that any bypass around a wastewater treatment system must be car sealed closed.

Section 12.04 states that the system must be maintained to assure that the system meets the effluent requirements.

314 CMR 15: The Prevention and Control of Oil Pollution in the Waters of the Commonwealth

It is not anticipated that any oils will be used or stored at the site. However, if any oils are used, this section could be an ARAR for the FS-12 plume response project.

TABLE 2-4

ARARS WITH SUBSTANTIVE REQUIREMENTS

LAWS	RULES & REGULATIONS	DESCRIPTION	AFFECTED PORTION OF REMEDY	SUBSTANTIVE REQUIREMENTS
FEDERAL				
Clean Air Act (CAA) of 1963, as amended [42 U.S.C. 2401]				
40 CFR 50 - National Primary and Secondary Ambient Air Quality Standards	40 CFR 50.6	National primary and secondary air quality standards for particulate matter.	Excavation operation	Limits the maximum 24-hour average ambient concentration of particulate matter (PM_{10}) to 150 $\mu g/m^3$ not to be exceeded more than once per year and the annual arithmetic means to 50 $\mu g/m^3$ as measured by the test method specified in 40 CFR 50 Appendix J, and averaging method specified in 40 CFR 50 Appendix K.
	40 CFR 50.9	National primary and secondary air quality standards for ozone.	Treatment Air Emissions	Sets maximum hourly average concentration at 235 $\mu g/m^3$, as measured by method given in 40 CFR 50 Appendix D, averaged as in 40 CFR 50 Appendix H.
40 CFR 61 - National Emissions Standards for Hazardous Air Pollutants	40 CFR 61.01	Identified substances that have been designated hazardous air pollutants, and for which a Federal Register notice has been published.	Treatment Air Emissions	Determine whether designated hazardous air pollutants are present.
	40 CFR 61.05-06	Specifies prohibited activities, describes procedures for determining whether construction or modification is involved, prescribes methods of applying for approval, and covers manner in which startup notification is to be provided.	Treatment Air Emissions	If hazardous air pollutants are present, regulatory approval must be obtained to construct or modify a source of pollutants.
	40 CFR 61.10-11	Specifies source reporting and waivers of compliance with a standard.	Treatment Air Emissions	If hazardous air pollutants are present, follow reporting/waiver requirements.
	40 CFR 61.12-14	Specifies compliance with emission standards. Also, specifies regulations for emission tests and monitoring requirements.	Treatment Air Emission	If hazardous air pollutants are present, follow compliance, testing, and monitoring requirements.

TABLE 2-4

ARARS WITH SUBSTANTIVE REQUIREMENTS

LAWS	RULES & REGULATIONS	DESCRIPTION	AFFECTED PORTION OF REMEDY	SUBSTANTIVE REQUIREMENTS
Solid Waste Disposal Act (SWDA) as mended by Resource Conservation and Recovery Act (RCRA) of 1976 [42 U.S.C. 6901]				
40 CFR 261 - Identification and Listing of Hazardous Wastes	40 CFR 261.1-7, 10, 11, 20-24, 30-33	Definition of Solid and Hazardous Wastes	Solid Residuals Management	Solid treatment residuals will require testing by the toxicity characteristic leaching procedure to determine if they are hazardous.
40 CFR 268 - Land Disposal Restrictions	40 CFR 268.30-37	Waste Specific Prohibitions	Solid and Liquid Residuals Management	No liquid wastes will be disposed of on land. If any of the waste codes listed in these sections are found, they will not be disposed of on land.
	40 CFR 268.40-43	Treatment Standards	Solid and Liquid Residuals Management	If wastes subject to 40 CFR 268.30-37 are found, treatment as specified in these sections will be applied.
	40 CFR 268-45	Treatment Standards for Hazardous Debris	Solid Residuals Management	If debris is found to be hazardous, it will be treated such that it is no longer contaminated with hazardous waste.
40 CFR 264 - Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities	40 CFR 264.351	Closure	Treatment System	All waste and residue must be removed from site at closure.
Clean Water Act (CWA) of 1977, as amended [33 U.S.C. 1251]				
40 CFR 122 - The National Pollutant Discharge Elimination System (NPDES)	40 CFR 122.1-7	Definitions and General Program Requirements	Liquid Residuals Management	Discusses purpose and scope, definitions, exclusions from NPDES permitting, prohibitions, permits, continuation of expiring permits, and confidentiality.

TABLE 2-4

ARARS WITH SUBSTANTIVE REQUIREMENTS

LAWS	RULES & REGULATIONS	DESCRIPTION	AFFECTED PORTION OF REMEDY	SUBSTANTIVE REQUIREMENTS
40 CFR 122 - The National Pollutant Discharge Elimination System (NPDES) (cont.)	40 CFR 122.21, 22, 28, 29	Permit Application and Special NPDES Program Requirements	Liquid Residuals Management	Specifies scope and details of NPDES permit applications.
	40 CFR 122.41-48	Permit Conditions	Liquid Residuals Management	Establishes limitations, standards, and other permit conditions applicable to all permits, including calculation of standards, permit duration, and compliance schedules. Specifies requirements for recording and reporting of monitoring results.
	40 CFR 122.49	Considerations Under Federal Law	Liquid Residuals Management	When applicable, the Wild and Scenic Rivers Act, National Historic Preservation Act, Endangered Species Act, Coastal Zone Management Act, Fish and Wildlife Coordination Act, and any executive orders will be complied with.
40 CFR 125 - Criteria and Standards for the National Pollutant Discharge Elimination System	40 CFR 125.1-3	Criteria and Standards for Imposing Technology-Based Treatment Requirements	Liquid Residuals Management	Establishes purpose, scope, definitions and criteria for determining standards for technology-based requirements.
	40 CFR 125.30-32	Criteria and Standards for Determining Fundamentally Different Factors	Liquid Residuals Management	Describes criteria and standards for establishing whether effluent limitations differing from CWA national limits should be imposed. These may be established if factors relating to the discharge are fundamentally different from those considered in promulgating national limits.
	40 CFR 125.100-104	Criteria and Standards for Best Management Practices	Liquid Residuals Management	Best management practices (BMPs) shall be specified to establish specific objectives for control of toxic and hazardous pollutants. BMPs may reflect requirements for spill prevention control and countermeasure plans.

TABLE 2-4

ARARS WITH SUBSTANTIVE REQUIREMENTS

LAWS	RULES & REGULATIONS	DESCRIPTION	AFFECTED PORTION OF REMEDY	SUBSTANTIVE REQUIREMENTS
40 CFR 136 - Guidelines Establishing Test Procedures for the Analysis of Pollutants	40 CFR 136.1-5, Appendices A-C	Analytical Procedures for NPDES Applications and Reports	Liquid Residuals Management	Specific methods will be used.
40 CFR 403 - General Pretreatment Regulations for Existing and New Sources of Pollution	40 CFR 403.1-7	Purpose, applicability, objectives, definitions, prohibited discharges, categorical standards, and removal credits.	Liquid Residuals Management	Pretreatment standards as promulgated by a POTW will be adhered to, if a discharge to POTW occurs. If fundamentally different factors (as defined in 40 CFR 125.30-32) exist, a variance will be prepared.
Public Health Service Act: Title XIV, as amended by the Safe Drinking Water Act of 1988 [42 U.S.C. 300 (f)]				
40 CFR 141 - National Primary Drinking Water Regulations	40 CFR 141.11, 12, 50, 51	Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs)	Liquid Residuals Management	MCLs and MCLGs for organic and inorganic chemicals may be required to be met if wastewater may reach drinking water sources.
	40 CFR 141.60-63	Revised Primary Drinking Water Regulations	Liquid Residuals Management	Revised MCLs and MCLGs for organic and inorganic chemicals sets best available technology for some organics. If these organics are found in wastewater that may reach drinking water sources, BAT will be applied.
40 CFR 143 - National Secondary Drinking Water Regulations	40 CFR 143.3	Secondary MCLs	Liquid Residuals Management	Secondary MCLs, which affect mostly aesthetic qualities of drinking water, may be required to be met if wastewater may reach drinking water sources.

2.7 BASIS FOR DESIGN

The FS-12 ETR system has a number of objectives which include (Strategic Plan AFCEE, 1996):

- Design, construct, and operate a full-scale ETR system.
- Contain, capture, and remediate the FS-12 plume.
- Minimize adverse impacts on Snake Pond and its surrounding environment.
- Monitor performance of treatment system.
- Avoid influencing the remedial system on the J. Braden Thompson plume.
- Minimize disturbance to private property.
- Monitor groundwater quality to assess performance and assist future design at other sites.

2.7.1 Extracted Water Concentrations

The MMR "Plume Containment System 60% Design", issued January 1996, (OpTech, 1996a) included a list of contaminants in the FS-12 plume that were used as a basis for preparation of the design. Since that time, the design basis for location of the extraction wells has been changed and more wells will be installed including wells in the "hot spot" of the plume. Because of the revision which includes wells located in the hot spot, the design basis concentrations have generally been increased from the concentrations used in the "60% design".

"60% Design" Concentrations

The extraction well location basis for the OpTech "60% design" was to locate all the extraction wells in the toe of the plume. Because all the water would be extracted from the toe, initial concentrations of contaminants would be very low but would increase with time as the higher concentration portions of the plume move toward the toe. To allow for the future increase in concentrations, the

system was designed to handle the average concentration in the plume, with a margin for safety.

Design Concentrations

Because some of the extraction wells are now located in the "hot spot" of the plume, a revised approach was used to recalculate the extracted water concentrations:

- A "Weighted Average" concentration was calculated using information from the monitoring wells that are located in the vicinity of the extraction wells. This average concentration was used for economic evaluations and for preparation of the material balance on the Process Flow Diagram (PFD). Note: The concentrations determined using this approach are believed to be conservatively high because they do not allow for clean water that will be drawn into the top and bottom of the plume.
- The concentrations in the "hot spot" only were also calculated. These concentrations were used to evaluate the performance of the proposed treatment system under a "worst case" scenario.

The following summarizes the concentrations determined for both the weighted average case and the hot spot case. The table also compares these concentrations with the concentrations included in the "60% design".

Contaminant	Concentration, micrograms/liter		
	Weighted Average	Hot Spot	"60% Design"
Benzene	356	1.167	60
Toluene	0.9	2.25	-
Chlorobenzene	2		-
Ethylbenzene	12	4.7	-
Chloroform	0.19	0.36	-
Xylene	17	35	-
1,1-DCE	8	31	-
TCE	0.02	0.69	-
1,2-Dibromoethene (EDB)	113	260	8.2
Napthalene	2.6	7	-
2-Methylnaphthalene	0.52	ND	-
Phenol	0.52	-	-
Iron	526	-	526
Manganese	65	-	65
TSS	2,500	2,500	22,000

A more complete discussion of individual contaminants is as follows:

- TSS (total suspended solids): The 2500 microgram/l design basis is based on the maximum practical capacity of the Greensand filters, and based on information from other wells in the area such as the CS-4 plume containment wells and the Coonamessett well is considered to be conservative. The concentrations listed in the Data Gap were not considered as representative of the TSS that would be expected in a full scale extraction system. The

previous TSS data was collected from monitoring wells with no sand pack (the underground formation was allowed to collapse around the screen). The extraction wells will have fully developed sand packs and will be operated long enough to remove fines from the area around the screen. This design basis concentration will be confirmed by sampling during pumping tests that are scheduled to be conducted at the site.

- The iron and manganese exist primarily in the wells that are located in the "hot spot". The dissolved oxygen concentration in the hot spot is low, which has allowed the iron and manganese to be reduced and go into solution. In the extraction well header, the water from wells with high metal concentrations will be mixed with water from wells with a high dissolved oxygen content. At this point the iron and manganese will begin to react with the DO and be precipitated. When the water reaches the treatment system, it is expected to be a mixture of soluble and precipitated metals. However, the sizing basis for the permanganate addition system conservatively assumed that all the metals will still be in solution.
- JP-4 fuel contains high concentrations of organic compounds with a higher molecular weight than benzene, such as: ethylbenzene, toluene, xylenes, napthalenes, etc. However, a review of the laboratory data indicates that these higher molecular weight compounds are not present in the plume in high concentrations.

2.7.2 Effluent Design Basis

Groundwater treatment levels will normally be based on non-detection of chemicals by U.S. EPA analytical methods Drinking Water 504 and 502. Method 504 (EDB only) has interference with chlorinated hydrocarbons. The results can give false positive readings. If a "hit" occurs, Method 524 will be used. These analytical methods are gas chromatography or mass spectrometer methods. The analysis for metals will be conducted by Solid Waste Method. Treatment will be

conducted to reduce the concentrations of the contaminants to those shown in Table 2-5. The meeting of such goals does not create any technical difficulty for the treatment units as they are designed.

TABLE 2-5

Cleanup Levels - Groundwater

Hazardous Substance	CAS No.[1]	Method[2]	PQL[3]	CRQL[4]	MCL[5]	Cleanup Level[6]
1,1-DCA	75-34-3	DW 502	0.07 ug/l	10 ug/l	5 ug/l	0.07 ug/l
EDB	106-93-4	DW 504	0.02 ug/l	-	5 ug/l	0.02 ug/l
1,2-DCE	107-06-2	DW 502	0.07 ug/l	5 ug/l	5 ug/l	0.07 ug/l
2-Methyl naphthalene	91-57-6	DW 502	0.5 ug/l	10 ug/l	10 ug/l	0.5 ug/l
Benzene	71-43-2	DW 502	0.1 ug/l	5 ug/l	5 ug/l	0.1 ug/l
Chlorobenzene	108-90-7	DW 502	0.1 ug/l	10 ug/l	1 mg/l	0.1 ug/l
Chloroform	67-66-3	DW 502	0.2 ug/l	10 ug/l	1 mg/l	0.2 ug/l
Ethyl benzene	100-41-4	DW 502	0.2 ug/l	10 ug/l	700 ug/l	0.2 ug/l
Iron	1543-83-10	SW 6010A	0.07 mg/l	100 ug/l	300 ug/l	300 mg/l
Manganese	7439-96-5	SW 6010A	0.02 mg/l	15 ug/l	50 ug/l	0.01 mg/l
Naphthalene	91-20-3	DW 502	0.5 ug/l	10 ug/l	-	0.5 ug/l
Phenol	108-95-2	DW 502	0.5ug/l	10 ug/l	10 ug/l	0.5 ug/l
PCE	127-18-4	DW 502	0.3 ug/l	5 ug/l	5 ug/l	0.3 ug/l
Toluene	108-88-3	DW 502	0.2 ug/l	10 ug/l	1,000 ug/l	0.2 ug/l
TCE	79-01-6	DW 502	0.03 ug/l	5 ug/l	5 ug/l	0.03 ug/l
Xylene	1330-20-7	DW 502	0.5 ug/l	10 ug/l	10,000ug/l	0.5 ug/l

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1. Chemical Abstracts Service registry number, this number is unique for each chemical and allows for efficient searching.
2. The U.S. EPA analytical method. The U.S. EPA provides analytical procedures to test solid wastes and drinking water.
3. Practical Quantification Limit as determined by the U.S. EPA. This is the lowest level at which a chemical can be accurately and reproducibly quantitated. Usually equal to the instrument detection limit multiplied by a factor of three to five, but varies for different chemicals and different samples. Ref. Quality Assurance Project Plan, HQ AFCEE Ver. 1.1, Feb. 1996.
4. The U.S. EPA Contract - required Quantitation Limit Chemical-specific levels that a CLP laboratory must be able to routinely and reliably detect and quantitate in specified samples.
5. The Maximum Contaminant Level (MCL) specified under Section 141 of the Federal Safe Drinking Water Act.
6. Cleanup Level is set ordinarily at the Practical Quantitation Limit (PQL).

Strictly interpreted, the detection limit (DL) is the lowest amount of a chemical that can be "seen" above the normal, random noise of an analytical instrument or method. A chemical present below that level cannot reliably be distinguished from noise. DLs are chemical-specific and instrument-specific and are determined by statistical treatment of multiple analyses in which the ratio of the lowest amount observed to the electronic noise level (i.e., the signal-to-noise ratio) is determined. On any given day, in any given sample, the calculated limit may not be attainable; however, a properly calculated limit can be used as an overall general measure of laboratory performance.

Two (2) types of DLs may be described; 1) instrument DLs (IDLs) and 2) method DLs (MDLs). The IDL is generally the lowest amount of a substance that can be detected by an instrument; it is a measure only of the DL for the instrument, and does not consider any effects that sample matrix, handling, and preparation may have. The MDL, on the other hand, takes into account the reagents, sample matrix, and preparation steps applied to a sample in specific analytical methods.

Due to the irregular nature of instrument or method noise, reproducible quantitation of a chemical is not possible at the DL. Generally, a factor of three to five is applied to the DL to obtain a practical quantitation limit (PQL), which is considered to be the lowest level at which a chemical may be accurately and reproducibly quanitated. This is the value used by Jacobs Engineering. DLs indicate the level at which a small amount would be "seen", whereas PQLs indicate the levels at which measurements can be "trusted". The CRQL is the chemical-specific level that a CLP laboratory must be able to routinely and reliably detect and quantitate is specific sample matrices, and may or may not be equal to the reported quantitation limit of a chemical. CRQL are updated each year by U.S. EPA.

2.8 DESIGN BASIS LIMITATIONS

As discussed previously, the design objectives for the FS-12 ETR system are in some cases conflicting. Therefore, to design a groundwater containment system for the FS-12 plume requires a balancing of design objectives to the degree possible, while attempting to satisfy the concerns of all stakeholders. To compensate for potential uncertainties, the FS-12 ETR system design incorporates considerable flexibility in acceptable system flow rates and water quality. However, it is important to understand the limitations of the FS-12 system design to provide a framework for project expectations.

2.8.1 Physical Capacity of FS-12 ETR System

The FS-12 ETR system has been designed to operate at a maximum system flow rate of approximately 1400 gpm and a minimum system flow rate of approximately 400 gpm. These flow rates are approximately 70 percent higher and 50 percent lower than the expected operating flow rate of 830 gpm. Individually, subsets of the FS-12 ETR system have the following operating limitations:

- Extraction and Reinjection Wells. The transmissivity of aquifer sediments at FS-12 will support groundwater extraction/reinjection rates more than 10 times higher than recommended extraction/reinjection rates for the FS-12 ETR system. Therefore, the primary limitation on groundwater extraction/reinjection rates for FS-12 will be the size of pumps selected for the extraction wells and the capacity of system piping and treatment plant processes. The extraction/reinjection well fences will be controlled by valves that can be adjusted separately at each extraction/reinjection well location to increase system flexibility.
- System Piping. The FS-12 ETR system piping is capable of operating at a flow rate within the 1400/400 gpm range with no modifications to the system. Flow rates up to 1700 gpm are possible.

- FS-12 Treatment Plant. The FS-12 Treatment Plant is capable of operating at a flow rate within the 1400/400 gpm range with no modifications to the system. By adding additional treatment components, the acceptable system flow rate could be increased to 1700 gpm.

Currently, it is not anticipated that it will be necessary to operate the FS-12 ETR system at flow rates greater than 1200 gpm.

2.8.2 Site Access

Access considerations at FS-12 are controlled by activities at Camp Good News. Every summer from June 25 to Labor Day weekend, camp activities prohibit access to Camp Good News property. As a result, all FS-12 activities must be coordinated to occur during non-summer months. The current schedule is to construct the FS-12 ETR system prior to June 25, 1997 and then begin plant startup in the fall of 1997. Proposed refinements to the FS-12 design, if required, must consider this access limitation.

2.8.3 Hydraulic Monitoring

The Draft Performance Monitoring Plan for the FS-12 ETR system will be submitted for review in December 1996. Details regarding performance monitoring for the FS-12 system will be included in this draft submittal. However, based on a preliminary analysis of potential aquifer drawdown and mounding produced by the FS-12 ETR well network it is apparent that traditional hydraulic monitoring to demonstrate capture using observation wells may have limited value. This potential operational difficulty is due to low pumping rates to meet the design objective of minimizing impact to Snake Pond and the surrounding ecological system at FS-12. This design limitation will increase the complexity and cost of performance monitoring at the site and potentially decrease the accuracy of performance monitoring. In general, groundwater extraction systems are designed to operate at pumping rates that exceed seasonal fluctuations to ensure plume capture can be easily achieved and demonstrated.

For the FS-12 plume, seasonal fluctuations will be much greater than the influence of the FS-12 system. In addition, at distances greater than 50 feet from extraction and reinjection well fences it is unlikely that groundwater elevation changes due to operation of the FS-12 system can be accurately measured. It is important that all stakeholders recognize this design limitation since it may directly affect the defensibility of performance monitoring for the FS-12 plume.

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3.0 DESCRIPTION OF TREATMENT PROCESS

The treatment process will consist of:

- Extraction wells
- Collection piping and an influent tank
- pH control
- Greensand filters to remove suspended solids, iron, and manganese.
- Solids settling and collection facilities
- A UV/peroxide system partially oxidize the organic contaminant.
- An activated carbon system to complete the removal of the toxic organics to below the detection limit
- An effluent tank
- Reinjection wells

Process Flow Diagrams (PFD's) and Process and Instrument Diagrams (P&ID's) showing the treatment system are included in Volume II.

The following is a brief description of the process. For a more complete description, see Section 4.0.

3.1 PROCESS DESCRIPTION

3.1.1 Extraction Wells

There will be thirty (30) extraction wells (1EW-101-1-30) supplying contaminated groundwater from the FS-12 plume to the Treatment Unit 1. The 30 well pumps (1EWP-101-1-30) will be controlled from a central location. The well pumps supply, through a double walled pipe header, the contaminated water to the treatment unit.

The double wall pipe providing secondary containment for the influent water will have leak detection at the low points along the header to ensure against leakage of the contaminated water along the supply route.

Flow control valves in each well determine the amount of raw water to the influent tank (1T-101) in the treatment unit. The well operation will be designed to be monitored from the treatment unit or from the remote control center.

3.1.2 Neutralization

The incoming water has a pH of between 5.2 and 6.5 with a low suspended solids (TSS) and low concentrations of iron (Fe^{+2}), manganese (Mn), benzene and ethylene dibromide (EDB). The iron and manganese in the Greensand filters (1-GS-101A/B/C/D) along with the suspended solids will be removed to improve the performance of the downstream treatment system. In order to effectively remove the iron and manganese in the Greensand filters the pH must be 6.2 or greater.

The pH will be adjusted to the proper level by the addition of 25% sodium hydroxide (NaOH) to the influent tank with a metering pump (1P-107A/B) from the caustic (NaOH) storage tank (1T-105). The caustic will be delivered by 3,000 gallon tank trucks.

The caustic addition is controlled by a pH meter which monitors influent tank pH and a flow meter on the incoming raw water system. These instruments transmit signals to a proportional flow indicator controller which controls the rate of caustic addition to the influent tank through an in-line mixer and eductors in the tank.

The pH will be maintained at the optimum level for iron and manganese removal in the Greensand filter.

Pumps 1-P-101A/B/C will take suction from influent Tank 101. There will be two pumps in service with one on stand-by. These pumps will discharge to the Greensand filters. There will be two recirculation lines on the discharge of these

pumps for the caustic addition equipment. One is a 1" line with the pH meter recirculating back to the suction line and one 3" line for caustic addition in the line mixer circulation back to ITIC-101. The pH recirculation line will be manually controlled and the caustic addition recirculation is controlled by a restrictive orifice.

3.1.3 Greensand Filters

Manganese Greensand filter beds are a dependable and cost effective method of removing iron and manganese. Manganese Greensand is a purple-black filter media processed from Glauconitic Greensand.

The Greensand filters will be regenerated by a continuous feed of potassium permanganate (KMnO4). The KMnO4 demand will be determined by the iron and manganese concentrations in the feed stream. The flow through each of the filters will be controlled by a flow meter on the inlet to the filter. The water passes through the filter which will be composed of a layer of anthracite as well as a layer of Greensand. The flow rate will be 2 - 5 GPM/sq. ft. so with the 10' diameter filters, the flow rate is 157 to 393 GPM per filter and with four (4) filters is 628 to 1572 GPM. The filter can build a differential pressure of 2 times the clean filter differential. There is a differential pressure control system which will start the backwash when the differential pressure reaches the prescribed maximum operating value.

When backwash is initiated, the flow to and from the filter will be cut off. The backwash inlet valve (the normal outlet) and the backwash outlet valve (the normal inlet) are both open. The backwash water will come from the effluent tank (1T-102) via the backwash pumps (1-P-103 A/B). The backwash water will go to the sedimentation tank (1T-103). Backwash will continue 15 to 20 minutes at 1000 GPM. The flow will then returned to normal.

The backwash water will go to the sedimentation tank (1T-103). The backwash will be a very thin slurry with some 30 pounds of solids in the 15,000 to 17,000 gallons of water. The slurry will be allowed to settle for 2 - 3 hours. After 3 hours, the solids will have settled having a 3% solids slurry at the tank bottom. The top 17,000 gallons will be pumped back to the influent tank for re-treatment.

Between backwashes, the processing rate will be sufficient to pull 1T-101 down to a level that can receive the 17,000 gallons of the next backwash. The sedimentation tank will receive about 55 gallons of 3% solids per day from the backwashes of one (1) Greensand filter per shift. The solids will accumulate in 1T-103 until a load of 2,000-3,000 gallons is available to load out a 3,000 gallon truck. The tank truck will be connected by hose to the slurry pump (1P-104) and the truck loaded from the bottom of the tank cone. Because of the possible solids handling problems when handling a slurry, the truck loading, the slurry pump and the sedimentation tank will have facilities for flushing and air blowing the lines. Secondary containment is also provided to collect any potential spills from the loading operation. The truck loading will be a manual operation. The backwashing and decanting are automated and do not require operator supervision.

There will be a flow control valve on the discharge of the recirculation pumps (1-P 105A/B) which pump the decanted liquor from the sedimentation tank back to the influent tank (1T-101). The backwash and the decantation pumping are automated. The flow control will permit adjustment of the pumping rate to allow coordination with the normal operation of the influent tank and to prevent overfilling.

3.1.4 UV/Oxidation

The flow process from the Greensand filters goes through the ultraviolet oxidation unit. Hydrogen peroxide will be added to the incoming stream in an in-line mixer upstream of the U.V. trains. Volatile organic compounds are rapidly oxidized in this unit when the hydrogen peroxide (H_2O_2) is exposed to ultraviolet light. Over 90% of the VOC's can be oxidized. The organic compounds treated in this case are benzene and ethylene dibromide.

The reactor will be a cylindrical stainless steel vessel at the center of which is a single high powered ultraviolet lamp. A quartz sleeve separates the lamp from the water. Inside each reactor, the U.V. light splits the H_2O_2 to form highly reactive hydroxyl radicals (OH) producing an oxidative environment. The OH radical initiates rapid oxidation reactions.

The hydrogen peroxide will be supplied in carboys which are connected to the metering pumps which add the 35% H_2O_2 in the determined amount to the in-line mixer upstream of the U.V. Unit.

There will be three trains operating in parallel, each train consisting of two reactors. Each of the three trains has a flow control valve on the inlet of the first reactor so that the total process flow can be balanced among the three trains. The units are equipped with safety interlocks protecting against lamp failure, lamp wiper failure, etc. There will be a by-pass around the entire unit.

3.1.5 Carbon Adsorption

The carbon adsorption system consists of three trains of two adsorbers each. The two adsorbers in each train operate in series. The adsorber with the freshest carbon will be the second unit in the series and serves as a polish filter. The valving arrangement with each train allows the necessary flexibility to accomplish

the various tasks of emptying, filling, forward and reverse series flow, single unit flow and parallel flow. The three trains operate in parallel.

Carbon, which will be delivered in hopper bottom trailers with 20,000 pound loads, are an adsorber refill. When the carbon in the lead adsorber in a train is spent, the carbon will be exchanged for fresh carbon.

Two trailers will be required for a carbon exchange. An empty trailer arrives first to receive the spent carbon from the spent adsorber. The carbon fill line on the empty trailer will be connected by a hose to the spent carbon line at the trailer service area. The spent carbon adsorber will be isolated from the production stream and the full stream of the train flows through the other adsorber which has been the polish filter. The spent catalyst adsorber will be pressurized to 30 psig. The empty truck vents are opened and the pressurized adsorber opened allowing the spent carbon to flow to the empty truck. The 4,000 gallons of water and the spent carbon of the adsorber are now in the trailer. The trailer water unloading line will be connected by hose to the backwash water line at the trailer station. The 15 psig air line will be connected to the trailer and the water blown to Tank 101. Secondary containment is provided around the carbon loading spot to collect any potential spills.

The spent carbon loaded trailer will be returned to a licensed firm for reactivation. The fresh carbon trailer will be located at the trailer station and connected by hose to the fresh carbon line. The empty adsorber will be filled with water and pressurized to 15 psig. Half of the water in the adsorber will be transferred to the trailer. This will leave water in the adsorber to serve as a cushion to protect the bottom distributor plate from shock when the fresh carbon is transferred.

The trailer will be pressurized and the fresh carbon and water will be transferred to the adsorber. The trailer will be disconnected. The adsorber will be backwashed to remove the fines and characterize the fresh carbon bed. The backwash takes about 15 minutes with 1,000 GPM flow. The fresh adsorber will now be put back into service as the polish filter in that train. The water level in 1T-101 must be checked before the carbon exchange operation will be started and the level maneuvered as necessary to handle the carbon transfer manipulations.

3.1.6 Treated Water

The water in 1T-102 will be treated and most of it is reinjected in the plume area from which it came. Pumps 1P-102A/B pump into the reinjection header. The flow will be controlled by the level in the tank (1T-102).

A part of the treated water will be used for the backwashing of the Greensand filter and the carbon exchange operation of the carbon adsorption system. There will also be in-plant flushing and washing operations.

The treated water going to the reinjection wells receives a controlled amount of H_2O_2 to replace the dissolved oxygen removed in processing. There will also be provisions for the shock, or continuous feed of NaOCl as a Biocide to control biological action and prevent biological plugging of the reinjection wells.

The treated water to the 30 reinjection wells will be regulated at each well head with an electric, remote-operated in-line motorized control valve in the well vault.

3.2 COMPLIANCE WITH THE REGULATORY REQUIREMENTS

The following sections discuss how the FS-12 plume response project meets the regulatory requirements described in Section 2.6.

3.2.1 Compliance with the Requirements of the Federal ARARs

Clean Air Act

Air emissions from the FS-12 plume response project will be minimal. There will be no emissions of carbon monoxide, nitrogen dioxides and sulfur dioxide. Emissions of particulates, VOCs, and hazardous air pollutants will be deminimus. The FS-12 plume response project does not include the installation of any boilers and fired heaters, and thus will not generate carbon monoxide, nitrogen dioxide, or sulfur dioxide.

Potassium permanganate will be handled in bags of crystals. The bags will be opened inside the treatment buildings where the permanganate will be dissolved in water. Because the permanganate is handled in crystal form, there will be minimal dusting and deminimus particulate air emissions.

Benzene has been detected in the groundwater plume, which has specific air emission control requirements under the NESHAP regulations. However, this compound is present in the groundwater in microgram/liter concentrations. The concentration is well below the trigger level for NESHAP control. The groundwater will be exposed to the air in the influent treatment tanks, which will have fixed roofs, but the concentration in the water is so low that air emissions will be deminimus. There are no air strippers or other treatment operations that will strip organics into the air. To confirm that the air emissions are negligible, the emissions were modeled using the USEPA "Water 8" program. Using this program, the calculated emissions are:

Compound	Air Emissions Mg/Year
Benzene	0.0277
BIS (2-Ethylhexyl) Phthalate	0.2514 E-07

Chloroform	0.1298 E-04
Dibromomethane	0.1692 E-02
Dibutylphthalate	0.6326 E-08
Dichloroethene (1,1)	0.2562 E-02
Ethylbenzene	0.1361 E-02
Methyl Napthalene (2-)	0.7279 E-06
Naphthalene	0.2132 E-04
Phenol	0.2926 E-07
Toluene	0.8803 E-04
Trichloroethylene	0.3690 E-05
Xylenes	0.1299 E-02
TOTAL ALL COMPOUNDS	0.03606

A number of the compounds on the list of hazardous air pollutants (HAPs) are present in the groundwater in micrograms/liter concentrations. However, because of the low concentrations in the water any air emissions will be deminimus.

Clean Water Act

Spill control has been designed into the FS-12 treatment system. In addition, the following treatment operations will be provided to remove contaminants from the groundwater before reinjection:

- pH control, to improve operation of the Greensand filters.
- Greensand filters for total suspended solids (TSS), iron, and manganese removal, as a pre-treatment for the downstream treatment systems.
- UV/oxidation for the partial removal of organic compounds, to reduce carbon consumption.
- Carbon treatment, either activated carbon or synthetic carbon, for the removal of organic compounds.

40CFR125 specifies that best management practices (BMPs) be used to prevent spills and leaks from discharging from the facility. The FS-12 treatment system will be installed on curbed concrete pads that will contain the contents of the largest tank (23,000 gallons). All truck loading and unloading operations will be conducted inside the pad area for containment. The concrete pads slope toward collection trenches which discharge into a containment sump. The containment volume is:

• Sump	942 gallons	
• Trenches	11,512	
• Sloped portion of concrete pad	<u>11,313</u>	
	TOTAL	23,767

In addition, a separate concrete dike is installed around the caustic tank. The dimensions of the concrete dike are 25 feet long x 11 feet wide x 3 feet high for a containment volume of 825 cubic feet.

40CFR403 sets maximum discharge concentrations for contaminants in the water. These concentration standards will be met because the design basis is to design to remove the toxic organic compounds to below the detection limit.

<u>Safe Drinking Water Act</u>

40CFR141 sets maximum contaminant levels (MCLs). The use of Greensand filters will reduce the concentration of iron and manganese to below the secondary MCLs. The specified iron and manganese discharge concentrations are:

• Iron	Effluent = 0.053 mg/l	MCL = 0.3 mg/liter
• Manganese	Effluent = 0.0065 mg/l	MCL = 0.05 mg/liter

The activated carbon filters will remove the higher molecular weight organic contaminants and lead to below the detection levels. The specified effluent concentrations are:

- Benzene Effluent = non detect (<0.5 mg/liter) MCL = 5 mg/liter
- EDB Effluent = non detect (<0.02 mg/liter) MCL = 0.02 mg/liter

Resource Conservation and Recovery Act (RCRA)

40CFR261 provides the definition of solid and hazardous waste. The following are the solid waste residuals that may be generated during the FS-12 plume response project, along with a discussion of what provisions will be made to handle the residuals if the residuals fail the TCLP test:

- Drill cuttings: The concentration of contaminants in the groundwater is in the microgram/liter range so it is unlikely that the cuttings will be a characteristic waste. However, the cuttings will be tested and handled as required by the regulations. (Installation activities only).
- The sludge removed from the Greensand filters will contain the suspended solids, iron, and manganese that is present in the influent. The sludge will also contain organic compounds in essentially the same concentration range as in the groundwater plumes. This sludge is not likely to fail the TCLP test, but the sludge loadout facilities have been designed to fully contain the volume of both the settling tank and the sludge hauling truck to meet the RCRA requirements for storage and truck loadout facilities. The sludge will be disposed of at a facility permitted to receive the waste. Since the sludge is not expected to exhibit the characteristics of a hazardous waste and will contain iron coagulants which will be beneficial to wastewater treatment systems, it may be attractive to send the sludge to a wastewater treatment system, possibly the existing wastewater treatment system at the base.
- Spent activated carbon may be sent offsite for regeneration. The organic compounds in the influent water will be concentrated in the carbon, so it is possible that the carbon will be an EP toxic waste. The carbon loadout facilities have been designed to meet the RCRA requirements for a truck loading facility. Containment has been provided to handle the full volume of

the carbon trucks. The spent carbon will be hauled to a carbon regeneration facility that is permitted to regenerate carbon that is a hazardous waste.

The extracted groundwater will not be a hazardous waste because the concentration of organics in the groundwater is in the micrograms/liter range. Nevertheless, the underground piping and the treatment system has been designed with leak and spill protection that meets RCRA requirements. The following safety factors have been built into the design:

- Double walled piping is used for all untreated groundwater. The double walled piping will be equipped with leak detection tape that will detect any failure of the main piping that releases water, plus will detect any water that infiltrates because of failure of the outer containment piping.
- All the tanks and vessels in the treatment area will either be elevated or will be mounted on concrete foundations that will allow visual observation of any leaks.
- All the treatment equipment and the truck unloading/loadout facilities will be located inside treatment buildings on a concrete pad designed to hold the entire contents of the largest tank. Since the treatment facilities are located inside buildings, the pads will not be required to contain rainfall.

3.2.2 Compliance with the Commonwealth of Massachusetts ARARs

302 CMR 6: Adopting Inland Wetland Orders

None of the activities associated with the FS-12 plume response project will impact wetlands.

310 CMR 6: Ambient Air Quality Standards for the Commonwealth of Massachusetts

This chapter lists the ambient air standards for sulfur dioxides, particulates, carbon monoxide, ozone, nitrogen oxides, and lead.

The project will not be installing any boilers or fired heaters so there will be no emissions of sulfur dioxide, carbon monoxide, or nitrogen oxides.

Potassium permanganate will be handled in bags of crystals, and will be emptied from the bags and dissolved in water. Because the materials are received in crystalline form, instead of powder or granules, there will be no particulate air emissions caused by dusting.

Organic compounds are only present in the plume in micrograms/liter concentrations and there are no treatment processes that strip organics into the air, so VOC emissions will be deminimus. Since the VOC emissions are deminimus, there will be no impact on ambient air ozone concentrations.

310 CMR 7: Air Pollution Control

The FS-12 plume response project is exempt from the air permitting requirements for the following reasons:

- The air emissions are less than one ton/year, and thus are exempted per 310 CMR 7.02 subsection (4)(a). The total calculated air emissions are 0.03607 mg/yr.
- 310 CMR 7.03 subsection (14) provides an exemption for groundwater remediation systems as long as control systems are used to achieve a 95% reduction in air emissions. As listed above, air emissions are deminimus, (<0.04 mg/yr.) so the exemption is not applicable.

An additional exemption provided by 314 CMR 0049, an exemption from the 95% control requirement if the air emission can be demonstrated as protective of the public health, will not be used by the project.

310 CMR 15: The State Environmental Code, Title 5: Standard Requirements for the Siting, Construction, Inspection, Upgrade and Expansion of On-site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage

Section 15.003 specifies that septage systems operated by an agency of the Federal Government is exempt from the requirement to obtain a construction permit. The FS-12 plume response project is being constructed and will be operated by the U. S. Department of Defense (DOD) and thus are exempt from permit requirements. However, this document contains all the information required to be included in a permit application and thus meets the requirements of this section.

Section 15.260 provides design information for tight tanks. This regulation restricts the use of tight tanks to special situations such as boat waste pumpouts and public water supply systems. The FS-12 treatment system location is remote from the base sewage treatment system, so it is not practical to tie into the existing system.

A "tight tank" will be used to collect sewage from the treatment system. A tight tank is considered to be a preferred alternate to a septic tank system.

310 CMR 22: Drinking Water Regulations

Chapters 22.05 through 22.11 list the maximum allowable concentrations of contaminants in drinking water and requires that certified labs be used to conduct the sample analysis. Bottled water that meets these standards will be supplied as drinking water at the FS-12 treatment system.

Part of the treated water from the effluent tank will be chlorinated for miscellaneous uses, other than injection, that require water that meets potable water standards. These miscellaneous uses include: toilets, safety showers, and

eyewash stations. The chlorinated water system is shown on the P&IDs, included in Volume II. This chlorinated water system meets the requirements of potable water systems for the following reasons:

- The effluent water will be routinely sampled and analyzed using USEPA method 504, to confirm that the treated water meets the drinking water standards. A Massachusetts certified lab will be used for all the analyses.
- The treatment system has been designed to remove iron and manganese to below the Massachusetts MCLs of 300 ppb iron and 50 ppb manganese.
- The treatment system has been designed to remove toxic organic contaminants to below the detection limit.
- The water will be chlorinated.
- The water will not be used for human consumption. (Bottled water will be provided for consumption).

<u>310 CMR 27: Underground Water Source Protection</u>

Section 27.03 lists the Classes of injection wells. The reinjection wells are Class V wells. They are not Class I through IV.

- Class I wells inject hazardous waste fluids below the lowermost drinking water aquifer.
- Class II wells inject fluid brought to the surface during oil or natural gas production.
- Class III wells inject fluids for the extraction of minerals.
- Class IV wells inject hazardous or radioactive wastes into or above an aquifer.

Class I through IV wells are prohibited.

Class V wells are only allowed as long as they do not cause or allow movement of contaminants into underground sources of drinking water.

The reinjection wells for the FS-12 plume remediation project are allowed by this project because:

- The design basis for the treatment system is to remove toxic organic contaminants to below the detection limit.
- Extraction wells and reinjection wells are located close together to prevent disturbing the natural groundwater flows in the area and thus not affect the flow of contamination toward any drinking water sources.

<u>310 CMR 30: Hazardous Waste</u>

Section 30.102 lists the methods for the identification of hazardous waste. Wastes which will be generated by construction or operation of the FS-12 plume containment system include:

- Drill cuttings and water generated during the installation and development of the wells.
- Solids collected during backwash of the filters
- Spent activated carbon

Of the three residues listed above, the first two are very unlikely to fail the TCLP test and thus are unlikely to be hazardous wastes. Nevertheless, all residues will be tested and will be handled and disposed of per the regulations. The organic compounds will concentrate in the activated carbon, so the spent carbon may fail the TCLP test. To be certain, the carbon loadout facilities are designed with full secondary containment per the hazardous waste regulations, and the carbon will be shipped for regeneration to facilities permitted to handle hazardous waste.

Section 30.354 lists the general requirements for hazardous waste treatment, storage, and disposal facilities (TSD). The groundwater in the FS-12 plume is very dilute, so the extracted groundwater will not be a hazardous waste. Even though it is not required by the regulations, both the piping from the extraction

wells and the treatment system is designed to meet the following secondary containment requirements.

- Double walled piping, with continuous leak detection cable, will be provided for the buried pipe from the extraction wells.
- All the tanks will be elevated or installed on foundations that will allow the visible detection of leaks.
- The treatment system will be installed over a concrete pad that will hold the contents of the largest tank, 23,000 gallons. The volumes of each section of the containment system are:

Volume of the sump	942 gallons
Volume of the trenches	11,512
Volume of the pad	11,312
Total	23,767

- Water stops will be used to seal the joints in the concrete
- Any spills or leaks will flow through trenches to a sump where an alarm will sound if the water level monitor detects any leaks or spills.

Section 30.402 lists the requirements for the transport of hazardous waste. Spent carbon from the treatment system may exhibit the characteristics of a hazardous waste. If the carbon is a hazardous waste it will be manifested, shipped to permitted regeneration facilities, and shipped using permitted haulers.

Section 30.693 lists design and installation requirements for hazardous waste tank systems. The FS-12 treatment system will not be a hazardous waste system, however, all the tanks will be designed with full secondary containment to meet the intention of this section.

Section 30.694 lists requirements for the containment and leaks from hazardous waste facilities. As mentioned above, even though the FS-12 plume containment

system is not a hazardous waste facility it will still be designed with full secondary containment and leak detection to meet the requirements of this section.

Sections 30.695, 696, and 697 list operating, inspection, and response requirements to prevent or control leaks and spills from hazardous waste facilities. To meet the requirements of these sections, the following items have been included in the design of the FS-12 plume containment facility:

- The underground piping from the wells will be constructed of double-walled HDPE pipe which is resistant to corrosion from both the extracted water and the environment.
- The tanks and treatment vessels are all either lined, or constructed of stainless steel, for corrosion resistance.
- High level alarms are provided on all tanks to prevent overfilling.
- The tanks all have covers and they are installed in a building, so freeboard for rainfall is not required.
- A high level alarm in the area sump will warn the operator of a spill or leak.

<u>310 CMR 40: Massachusetts Contingency Plan</u>

Section 40.0041 states that any water discharged within 200 feet of "Outstanding Resource Water" must meet groundwater quality standards and a permit is required for discharge to the groundwater. The contents of this document provide the information required in a permit application. Also, the quality of water discharged from the FS-12 plume containment facility will meet all the required groundwater quality standards. The contaminants in the discharge from the treatment system will all be below the MCLs and secondary MCLs. The system is further designed to remove toxic organic contaminants to below their respective detection limits.

Section 40.0045 lists specific requirements for the discharge of remediation effluent to the groundwater. The following describes how the effluent from the FS-12 plume containment project meets the requirements of this section:

The discharge must meet the requirements of 314 CMR 6.0:

- The iron concentration will be less than 0.3 mg/l. Iron will be removed in the Greensand filters as a pre-treatment to prevent fouling the carbon beds.
- The manganese concentration will be less than 0.05 mg/l. Manganese will be removed in the Greensand filters.
- The total dissolved solids must be less than 1000 mg/l to meet the requirements.. The expected concentration is essentially the same as the existing groundwater concentration (approximately 34 mg/l), thus meeting this requirement.
- The influent water will be neutralized if required to remove the iron and manganese. The re-injected water will either be at the pH of the natural groundwater, or will be neutralized to a pH between 6.5 and 8.5.
- The nitrate concentration must be less than 10 mg/l. The treatment system will not add nitrate and thus will not affect the concentration of this compound in the plume. Nitrate is less than 10 mg/l based on past plume sampling.
- The concentration of all other contaminants in the plume will be less than the MCLs and secondary MCLs.
- Facilities have been provided to allow the injection of sodium hypochlorite into the reinjection water, if needed, to control biological fouling around the reinjection wells. Since chlorine is not stable, the hypochlorite will be reduced to sodium chloride in the groundwater.
- Facilities are also provided for the injection of hydrogen peroxide to raise the dissolved oxygen concentration of the groundwater.

The discharge will not cause groundwater mounding within two feet of the surface for the following reasons:

- The treated water is being reinjected in close proximity to the point where the water is being extracted.
- The depth to groundwater is between 7 and 35 feet in the area of the reinjection wells.
- The groundwater modeling shows a mounding of only 0.15 feet in the area of the reinjection wells, see Figures 3-1 and 3-2. Thus, the water level in Snake Pond will not be affected.
- The system will be started up slowly.

The discharge will not result in flooding or breakout to the ground surface for the reasons listed above.

The discharge will not exacerbate existing conditions or impair the remediation of existing conditions because the treated water is being reinjected in the vicinity of where the water is extracted.

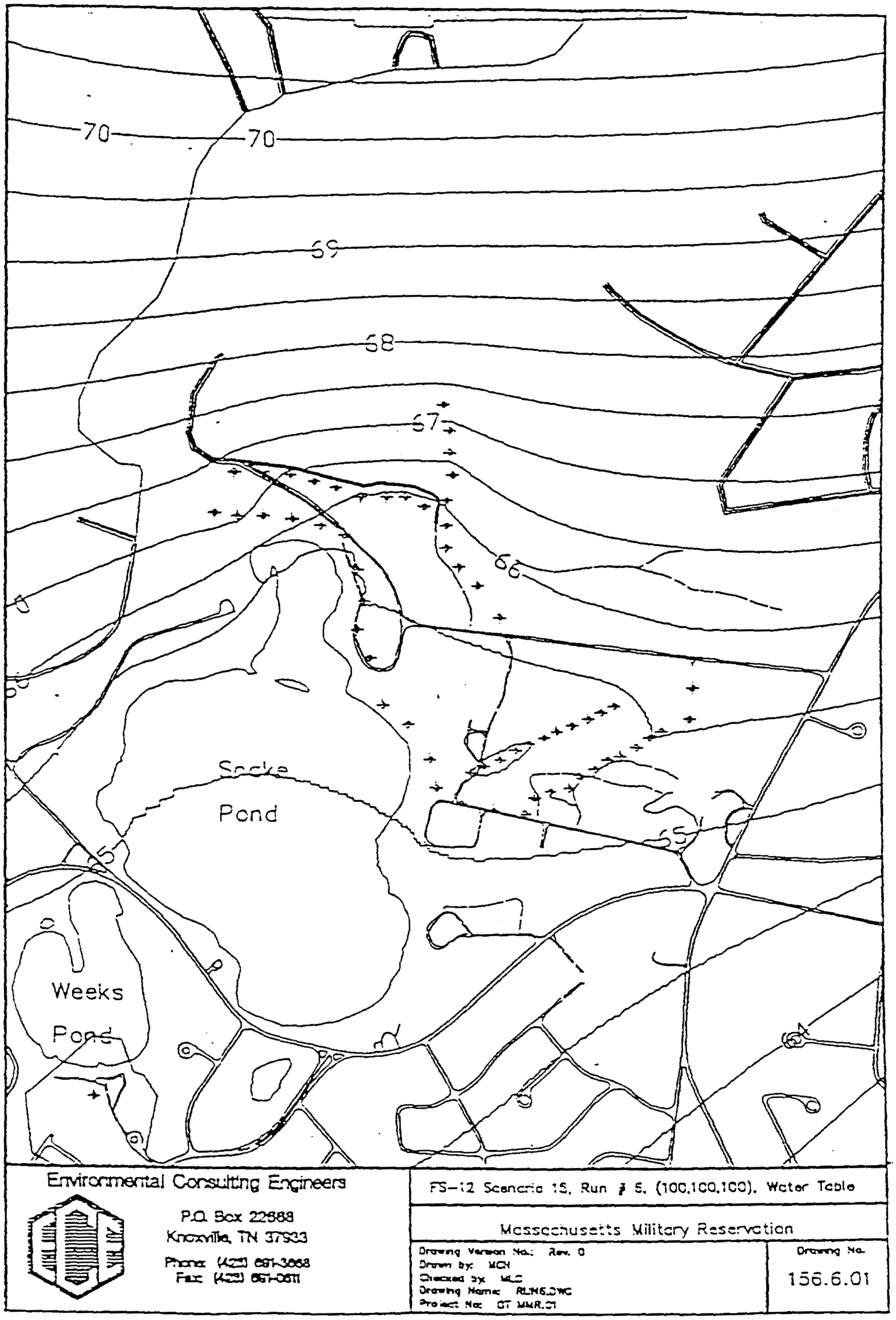
Section 40.0049 allows an exemption for groundwater remediation projects of the 95% control requirements for air emissions, if it can be demonstrated that the emissions present no risk to public health. The concentration of VOCs in the plume are so low and there are no treatment activities that strip VOCs to the air, so air emissions are deminimis and use of this exemption is not required.

Section 40.0874 lists the contents of a Remedial Implementation Plan (RIP). The requirements of this section are satisfied by submission of this report as demonstrated by the following cross reference between the requirements in this section (section 3.2) and the contents of this report:

- The goals of the project are listed in section 2.0, Basis of Design

- All new information about the site is included in section 2.0
- Disposal site maps are included in section 1.0, Introduction, and in Volume II.

Figure 3-1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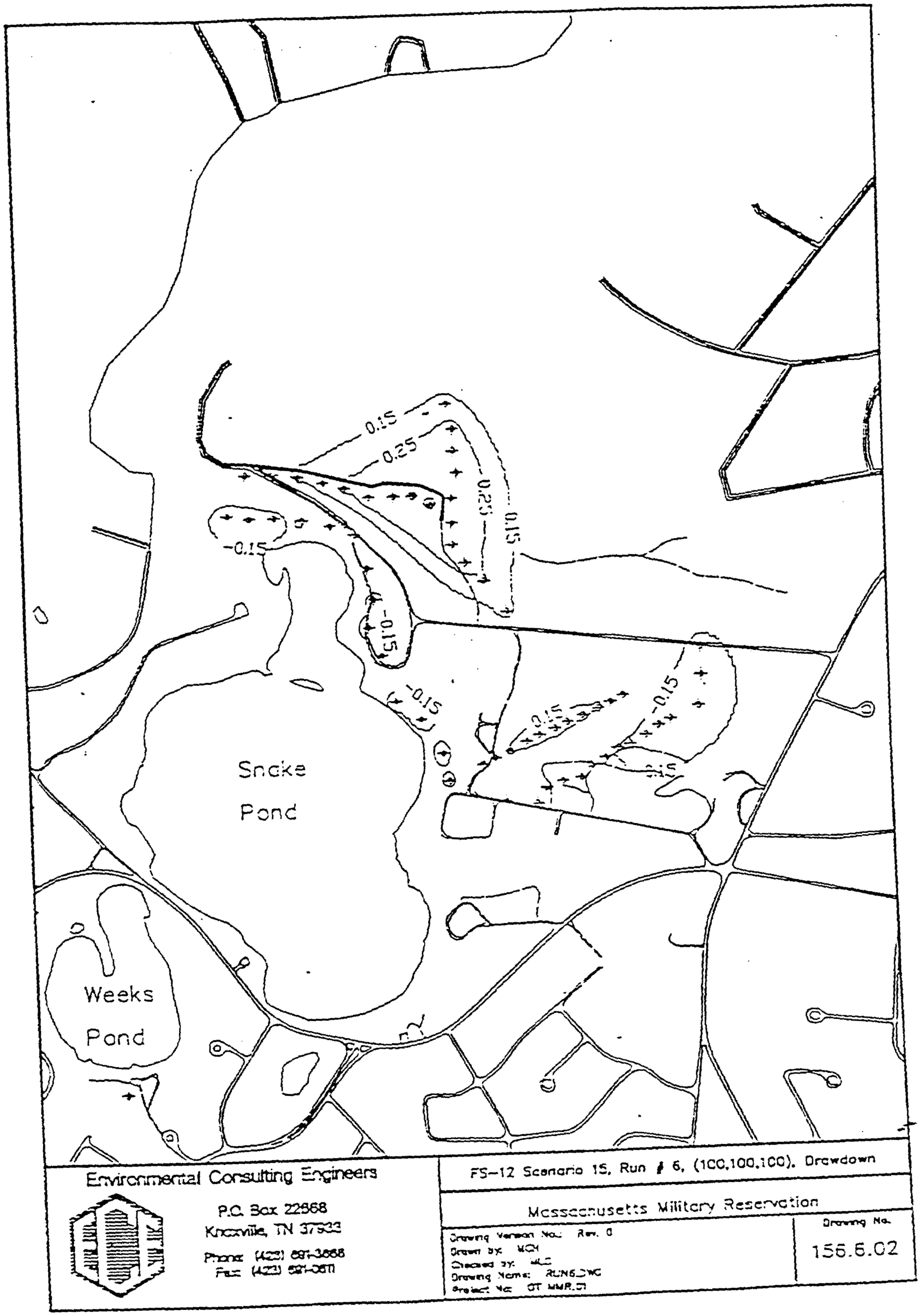
Environmental Consulting Engineers
P.O. Box 22688
Knoxville, TN 37933
Phone: (423) 691-3668
Fax: (423) 691-0611
FS-12 Scenario 15, Run # 6, (100,100,100), Water Table
Massachusetts Military Reservation
Drawing Version No.: Rev. 0
Drawn by: MCH
Checked by: MLC
Drawing Name: RUN6.DWG
Project No: GT MMR.01
Drawing No.
156.6.01

Figure 3-2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Environmental Consulting Engineers
P.O. Box 22668
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FS-12 Scenario 15, Run # 6, (100,100,100). Drawdown
Massachusetts Military Reservation
Drawing No.
156.6.02

- A description of the characteristics and quantity of the contaminated groundwater is included in section 2.0.
- A detailed description of the treatment units is included in section 4.0, Description and Layout for Key System Components, and in section 5.0, Extraction and Reinjection Systems.
- Relevant design and operation parameters are listed in section 3.0, Description of Treatment Processes, which also includes information on pilot tests that demonstrate the efficiency of the treatment systems.
- Design features for control of hazardous material spills and accidental discharges are discussed in section 4.3, Treatment System Containment.
- The management of residuals is discussed in section 4.0 and in section 6.0, Operational Philosophy and Safeguards.
- The identification of site-specific characteristics is included in section 2.0.
- A discussion of the measures taken to protect the environment is included in sections 2.0 and 3.0.
- A description of the inspection and monitoring is included in section 6.0

Section 40.0890 lists the requirements for operation and maintenance of the remedial action. The following describes how the requirements of this section will be met:

- The effluent from the treatment system will be sampled and analyzed to insure that the treatment requirements are being met.
- Monitoring wells are being installed. These wells will be sampled and analyzed, plus groundwater levels will be determined, to insure that the FS-12 plume is being contained as required.
- Operating and maintenance records will be maintained at the site.
- The equipment will be inspected and monitored as required to maintain the performance efficiency of the equipment.

314 CMR 2: Permit Procedures

This section states that the discharge to groundwater be permitted. The contents of this report provides the information required for permitting.

314 CMR 5: Groundwater Discharge Permit Program

Section 5.03 states that a permit application must be filed before treated water can be discharged below the land surface. This report provides the information required for the permit application.

Section 5.04 requires that a discharge permit be obtained for any stormwater that has come in contact with process wastes. As shown on the treatment system layout drawings in Volume II, secondary containment is provided for the extracted water and treatment system plus the treatment system will be located in a building to insure that stormwater will not contact the process wastes.

Section 5.10 lists effluent concentration limits. The FS-12 plume containment system will meet the primary effluent limits for Class I and Class II groundwaters as follows:

- Toxic pollutants will be removed by the treatment system to well below the MCLs. In fact, the treatment system has been designed to remove toxic organic contaminants to below the detection limit.
- The concentrations, in the FS-12 plume, of all other primary contaminants are below the listed treatment levels listed in this section.

The treatment system will also meet the following secondary effluent limitations:

- Iron will be removed to below 0.3 mg/l.
- Manganese will be removed to below 0.05 mg/l.
- The pH will either be the same as the pH of the natural groundwater, or will be adjusted to between 6.5 and 8.5.

- Nitrate nitrogen will be below 10 mg/l. The treatment system will not change the nitrate nitrogen concentration, which is below 10 mg/l in the plume.
- The total nitrogen concentration will be below 10 mg/l. The treatment system will not add nitrogen. If high molecular weight nitrogen compounds are present they will be removed by the treatment system so the reinjected water will be at or below the natural concentration in the FS-12 plume.
- The chloride concentration will be below 250 mg/l. The natural chloride concentration in the plume is approximately 10 mg/l this will not be changed by the treatment system.
- The total dissolved solid concentration will be less than 1000 mg/l. The TDS concentration in the FS-12 plume is approximately 34. This will be increased by less than 1% because of the addition of caustic for neutralization of the influent.
- Facilities are provided to add sodium hypochlorite to the water, if required, to control biological fouling around the reinjection wells. This may produce localized concentrations of chlorine in the groundwater, but the chlorine will react with organic compounds and soil and will quickly be reduced to sodium chloride in the groundwater.
- Facilities are provided to add hydrogen peroxide to the reinjected water to raise the dissolved oxygen content.

Section 5.19 lists specific requirements for the discharge to the groundwater that are being met by the FS-12 plume containment system as follows:

- The discharge did not violate the surface water or groundwater quality standards (see the discussions in the previous sections).
- The concentrations in the discharge are well below the requirements of 40CFR307(a).
- There are no lines that will allow bypass of the treatment system.

314 CMR 6: Groundwater Quality Standards

Section 6.06 lists minimum groundwater quality standards (see the previous discussion on the required groundwater discharge concentrations).

Section 6.07 states that a permit is required to discharge to the groundwater. This report satisfies the requirements for a permit application.

314 CMR 8: Supplemental Requirements for Hazardous Waste Management Facilities

This section requires that any wastewater units that treat, store, or dispose of hazardous waste generated at the site must comply with 310 CMR 30 (see the previous writeup on section 310 CMR 30 for a discussion of compliance with this section).

314 CMR 12: Operation and Maintenance and Pretreatment Standards for Wastewater Treatment

Section 12.03 states that any bypass around a wastewater system must be carsealed closed. There are no bypasses around the FS-12 treatment system.

Section 12.04 states that the system must be maintained to assure that the system meets the effluent requirements. A detailed maintenance plan well be prepared that will spell out the requirements needed to assure maintenance of the facility.

314 CMR 15: The Prevention and Control of Oil Pollution in the Waters of the Commonwealth

The FS-12 treatment system design does not include the storage or use of oils at the site. However, the treatment system design provides for the full containment of spills and will meet the Best Management Practices (BMPs) for spill containment, if oils are stored at the site in the future.

A concrete pad will be provided at the treatment area. The concrete pad combined with trenches and dikes will hold the volume of the largest tank (23,000 gallons). An additional dike is provided that will hold the contents of the caustic storage tank (4500 gallons).

3.3 PILOT TESTS AND COMMERCIAL EXPERIENCE

Pilot tests were conducted on groundwater collected at MMR to demonstrate that the contaminants in the groundwater to could be removed to concentrations below the detection limit. The information from these pilot tests was then supplemented with information from pilot tests conducted on groundwater from other locations, and on the operating experience of commercial carbon treatment systems. The pilot test results combined with other supplemental information demonstrate that:

- Activated carbon will reduce the organic contaminants of concern to below the detection limit. Removal of the contaminants to below the detection limit can be achieved with a residence in the carbon of as little as 4.5 minutes.
- Activated carbon, preceded by a UV/peroxide system, is an economically viable treatment option. The estimated carbon consumption is 160,000 lbs/year, eight carbon beds/year which is equivalent to replacing one carbon bed every 1.5 months. A residence time in the carbon of between 10 and 15 minutes is required to effectively use the capacity of the carbon, and to minimize the carbon replacement frequency.
- Greensand filters will reduce the concentrations of iron and manganese to well below the MCLs of 300 and 50 micrograms/l respectively.

Specific sources of information used for design of the main treatment facility systems included:

Activated Carbon System

- Laboratory "Isotherms" which define the capacity of carbon to remove various contaminants.
- Granular activated carbon vendor recommendations
- Pilot tests conducted on groundwater obtained from the FS-12 plume and the Eastern Briarwood plumes.
- The performance of systems operating to remove EDB from groundwater in Florida.
- The performance of systems treating groundwater in Massachusetts.

UV/Peroxide System

- Pilot tests conducted on groundwater obtained from the FS-12 plume
- Pilot tests conducted on groundwater from other locations
- Vendor recommendations

Greensand Filters System

- Vendor recommendations
- Literature on the removal of iron and manganese from drinking water

3.3.1 Granular Activated Carbon

The information used to size the granular activated carbon system was taken from a number of sources:

- Laboratory isotherms
- Granular activated carbon vendor recommendations
- Pilot test data
- The performance of commercial systems in full scale operation

Laboratory Isotherms

Laboratory isotherms are used to conduct the preliminary screening of the economics and effectiveness of removing contaminants from water. The isotherms show the quantity of contaminant that can be adsorbed on a gram of carbon, at various contaminant concentrations. The capacity of the carbon is measured at different concentrations and the results are plotted on log-log paper, which produces a straight line and allows determination of the slope and intercept of the line (see Appendix C for a more thorough discussion on isotherms).

Isotherms used to screen the effectiveness of carbon in treating the plumes at MMR were obtained from the following sources:

- The USEPA RREL database
- Isotherms developed by Calgon Corporation

The isotherms from both the RREL database and from Calgon both demonstrate that granular activated carbon is a viable approach to removing the following contaminants from groundwater, the carbon has a strong affinity to adsorb the following compounds:

- Trichloroethene (TCE)
- Perchloroethene (PCE)
- 1.1-Dichloroethene (1,1-DCE)
- 1,2-Dibromoethane (EDB)
- Benzene
- Toluene
- Ethylbenzene
- Xylenes
- Napthalene

Isotherms for the above compounds were used to calculate the consumption of carbon that would be expected, if a granular activated carbon system is installed downstream of a UV/peroxide system. The calculated carbon consumption is 160,000 lbs/year. which is equivalent to replacing eight carbon beds/year or a carbon bed every 1.5 months. These calculations demonstrate that the use of granular activated carbon is a viable treatment option.

Vendors Recommendations

Vendor recommendations on the use of activated carbon in treating the MMR plumes was received on two occasions:

- During procurement of the carbon systems for the Interim Wellhead Treatment System for the Town of Falmouth (Coonamessett Well).
- During development of the original design basis for treatment of the MMR plumes.

Requests for proposals were issued to carbon vendors, for a carbon treatment system to treat the discharge from the Coonamessett Well. To be conservative, the requests for proposal listed the following highest concentrations of contaminants detected in the CS-4 plume:

EDB	0.14 micrograms/l
TCE	13 micrograms/l
Toluene	24 micrograms/l
PCE	24 micrograms/l
1,1-DCE	17 micrograms/l
1,1,2,2-PCA	56 micrograms/l

Three vendors quoted activated carbon treatment systems. All three vendors, including the selected vendor (Calgon) recommended the use of two 20,000 pound carbon beds. The vendors stated that the residence time in each bed would

be 7.5 minutes, which based on their experience, was a long enough contact time to reduce the above concentrations to below the detection limit. These recommendations are consistent with pilot plant data which demonstrated that non-detect concentrations can be achieved with a 4.5 minute residence time.

In February, 1995 Calgon Corporation was asked to provide recommendations for carbon system contact times for each of the MMR plumes under consideration at the time. The following was Calgon's recommendations:

Plume	Contact Time, min.	Breakthrough Contaminant
FS-12	7.0	EDB
SD-5	7.5	TCE, 1,2-DCE, PCE
LF-1	10.0	Vinyl Chloride
CS-10	7.5	TCE, 1,2-DCE, PCE
Ashumet	8.7	TCE, 1,2-DCE, PCE

Based on the above recommendations, a design basis contact time, for the carbon systems at every plume, was set at 10 minutes. The 10 minutes was selected, to be conservative, to match the highest recommendation for any of the plumes.

In summary, based on vendor recommendations the design residence time for the FS-12 carbon system should be between 7.0 minutes and 10 minutes. This is a longer residence time than the 4.5 minutes demonstrated, in pilot tests, to remove the organic compounds of concern to below the detection limit.

Pilot Test Data

During 1995, samples were collected from the FS-12 and Eastern Briarwood plumes, and pilot tests were conducted to demonstrate that granular activated carbon could be used to reduce the concentrations of both organic compounds (EDB and benzene) and lead to below the detection limits.

EDB and Benzene Removal Pilot Tests

During the evaluation of treatment options for contaminant plumes at MMR, pilot tests were conducted to determine the removal efficiency of EDB and benzene using activated carbon. The tests were conducted by HPW Systems of Humble, Texas in November 1995.

The pilot system consisted of a 55 gallon drum of Calgon activated carbon. The drum contained approximately six cubic feet of carbon. The water tested was collected from monitoring well GMW-20, located in the "hot spot" of the FS-12 plume. This well was tested because of its high known concentrations of both benzene and EDB. The measured benzene concentration was 1800 micrograms/l, and the EDB concentration was 300 micrograms/l. These concentrations are more than twice as high as the concentrations expected in the feed to the FS-12 treatment system.

The flow rate through the treatment system was 10 gpm for a contact time of 4.5 minutes. During these tests both the benzene and the EDB were removed to below the detection limit as indicated by the following data:

	Influent, ppb	Effluent, ppb
Benzene	1800	ND(<5.0)
EDB	300	ND(<0.015)

This pilot test demonstrates that with a residence time of 4.5 minutes in the carbon bed, the EDB and benzene concentrations can be reduced to below the detection limits, from considerably higher concentrations than are expected in the treatment system influent.

Lead Removal Pilot Tests

From September 26 through September 28, 1995, onsite tests were conducted to demonstrate that granular activated carbon could be used to reduce lead concentrations in the groundwater to below the detection limit.

The water for the test was collected from monitoring well FTA-3/MW-3 in the Eastern Briarwood plume. The water from this well contained 3.6 ppb lead, which is in excess of the concentration expected in the FS-12 plume. The test was conducted using a 55 gallon drum that contained approximately 6 cubic feet of carbon. The flow rate to the carbon was 5 gpm, which is equivalent to a contact time of 9 minutes. The following were the results of the pilot tests:

Influent Sample	3.6 ppb
Effluent after 200 gallons	ND (<1.0 ppb)
Effluent after 1000 gallons	ND (<1.0 ppb)

The results show that activated carbon can remove lead from the MMR groundwater. The lead can be removed to below the detection limit using a residence time in the carbon bed of 9 minutes.

Note: Additional information on the pilot plant test work is contained in the "Draft Final, Installation Restoration Program, Plume Containment Design Analysis Plan, Volume IV, Appendices A - C", dated January 1996.

Performance of Commercial Systems in Full Scale Operation

Granular activated carbon is being successfully used in a number of commercial operations, a number of which are in Massachusetts, to remove contaminants from groundwater and drinking water to below the detection limits. Information on the following systems are included in Appendix C:

- Removing EDB from drinking water (Florida)

- Potable Groundwater Treatment system (Groveland, Massachusetts)
- Potable Groundwater Treatment system (Town of Marshfield, Massachusetts)
- Activated Carbon Treatment Restores Acton Water Supply (Acton, Massachusetts)

The first article is the result of work conducted in Florida on the treatment of potable water contaminated with EDB. Activated carbon has been used extensively to reduce the EDB concentrations in the groundwater to below the detection limit of 0.02 micrograms/l. Treatment systems described in the article include:

- Initial tests on two private wells that reduced the EDB concentrations from 10 and 700 microgram/l respectively, to below 0.02 micrograms/l. These designs have since been expanded to treat the water from 500 private wells.
- Carbon systems have been installed to treat 9 public water systems, with capacities up to 4.3 MM gallons/day. The design residence time of the systems ranges from 5 to 12 minutes.
- Extensive data collected on two systems demonstrated that the carbon consumption closely matched the consumption predicted from laboratory tests.

Carbon beds installed to treat potable water being discharged from Groveland Well No. 1 in Groveland, Massachusetts has been reducing TCE concentrations from 400 ppb to less than 2.5 ppb. The system operates with two carbon beds in series with a residence time of 13 minutes/bed or 26 minutes total.

Carbon beds installed to treat the water from Furnace Brook No. 1 well, in the Town of Marshfield, Massachusetts, reduce the PCE concentration in the potable water from 30 ppb to below the detection limit (<1 ppb). Two carbon beds operate in parallel, each with a residence time of 15 minutes.

Two carbon beds were installed in series to treat the potable water from Assabet No. 1 well in Acton, Massachusetts. The system has successfully treated groundwater containing over 150 ppb of TCE and 1,1-DCE to meet the standard of less than 5 ppb total VOCs. The residence time in the carbon system is 15 minutes/bed.

3.3.2 UV/Peroxide System

Activated carbon can remove the influent organic contaminants of concern to below the detection limit even if the UV/Peroxide system is not installed. However, installation of a UV/peroxide system is economically sound. The UV/peroxide destroys organic compounds upstream of the carbon and thus reduces the consumption of carbon.

Design of the UV/peroxide system is based on pilot tests conducted using groundwater obtained from the FS-12 plume. While these pilot tests were used to define the size and performance of the proposed system, this design was verified using data from other pilot plant tests and based on vendor recommendations.

Pilot Tests

In August 1995, pilot tests were conducted on water obtained from monitoring well GMW-20 in the FS-12 plume. Water from this well was used for the tests because the well is located in the hot spot of the plume and was known to have a high benzene and EDB concentration. An analysis of the water used for the pilot tests is as follows:

Benzene	445 ppb	Spiked to 842 ppb
EDB	193 ppb	Spiked to 898 ppb
pH	6.5 ppb	
TSS	<10 mg/l	

COD	35 mg/l
Iron	<1 mg/l
Alkalinity	60 mg/l
Chloride	8.5 mg/l
Nitrate	<1 mg/l

The UV/peroxide systems are designed based on both the required peroxide concentration and on the power input to the UV lamps, expressed as kWh/1000 gallons of water. Pilot tests were conducted at peroxide concentrations of 50 and 100 ppm and at power doses (EE/Os) of 0, 3.2, 6.4, 9.5, 12.7, and 15.9 kWh/1000 gallons. Appendix D contains figures showing the effluent benzene and EDB concentrations as a function of peroxide concentration and EE/O

The optimum removal was determined, based on the pilot tests, to be a 90% benzene removal. This 90 % was achieved with a peroxide concentration of 50 ppm and an EE/O interpolated to be 2.7 kWh/1000 gallons. EDB is not as easy to remove in a UV/peroxide system as benzene. Using this design basis, the EDB removal is only 30%.

<u>Pilot Tests at Groveland, Massachusetts</u>

Pilot tests were conducted to determine the economics of using a UV/oxidation system to treat TCE contaminated water in Groveland. The tests were conducted on groundwater contaminated with TCE and 1,2-DCE. During these tests, the optimum operating condition was determined to be an EE/O of 1.5 with a peroxide concentration of 25 ppm. The EE/O value is below the 2.7 recommended for the FS-12 treatment system. The proposed treatment at FS-12 will have a higher power input/1000 gallons than is proposed for Groveland.

Vendor Recommendations

The UV/peroxide vendor (SolarChem), who performed the pilot tests on the water from FS-12 has indicated that they believe that the proposed design of the treatment system is conservative. Solarchem's data indicates that using an EE/O of 2.7 should result in a 96% benzene destruction, instead of the 90% used as a basis for design. A copy of the Solarchem recommendation is included in Appendix D.

3.3.3 Greensand Filter Design

Based on recommendations from the Greensand filter vendors, pilot tests were not conducted to verify the performance of the filters. The vendors indicated that the use of Greensand filters to remove iron and manganese from drinking water supplies is a standard technology, with hundreds of systems in operation in the United States. A number of vendors were presented with the required iron and manganese treatment levels:

Iron	Influent = 526 mg/l	Effluent = <53 mg/l
Manganese	Influent = 65	Effluent = <6.5

Each vendor indicated that the above proposed treatment concentrations can be easily achieved using Greensand filter technology.

Appendix E contains the standard Greensand literature of the following companies:

- Kisko Water Treatment Company
- Roberts Filter Manufacturing Company

The literature from these companies contains the following design information that was used as a basis for sizing the FS-12 treatment system:

Potassium permanganate addition = (1 X ppm iron) plus (2 X ppm manganese)

Flow rate through the filter = 2 to 5 gpm/ft^2

Allowable solids loading = 7000 $grains/ft^2$ (one lb/ft^2)

Required backwash rate = 12 gpm/ft^2

3.4 Alternate Technologies Considered

A review of the potentially applicable process technology types and process options were evaluated with respect to technical implementability. Chemical treatment technology has been identified as the response action for the MMR's plumes. A technical analysis of the prime options was examined for reliability, implementability, safety, and likelihood of meeting the treatment goals. A cost analysis, including capital and construction estimates was considered. Finally, a number of institutional concerns were addressed, including regulatory considerations, on-site and off-site requirements, worker health and safety issues, worker and community relations benefits, and the ability to maintain all environmental and ecological protection considerations.

Description of Process Technologies Considered

Chemical treatment of groundwater is the process by which hazardous wastes are chemically changed to remove toxic contaminants. The types of treatment included in this review are oxidation/reduction, ozonation, ion exchange, air stripping, membrane and ion exchange for the treatment of organic contamination. To prepare the water for organic treatment the suspended solids, iron, and manganese need to be removed.

Sand filters are frequently used to remove fine sediment or silts from water. This is straight forward technology that has been used for centuries. Sediment is normally removed as a first step in water treatment. This allows the water to flow

through other process equipment with minimum plugging and less treatment interference.

Treatment is also required to remove the heavy metals (iron and manganese). Four technologies were reviewed. They included a Greensand filter, resins, chelation, and chemical perception. The Greensand filter was selected based on operational, maintenance and reliability requirements, and because it can also serve as a sand filter to remove suspended solids.

The next step is to remove the organic chemicals of concern. Seven technologies were evaluated. They are UV/oxidation, ozonation, clays, air stripping, ion exchange, membrane, and synthetic carbon (see Figure 3-3). A brief description of the technologies follows:

- UV/oxidation is a technology in which chemical reactions cause atoms or groups of atoms to lose electrons, hence oxidation/reduction is the transfer of electrons. In this process the reactions usually cause the contaminates to oxidize. The addition of oxygen breaks down organic waste or chemicals such as benzene, phenols, and organic sulfur compounds. Peroxide is the oxidizing agent normally used in conjunction with UV.
- Ozonation is a technology involving the use of ozone as an oxidizing agent. Ozone is produced with corona discharge technology (water or air is subjected to a high energy electric arc), and must be produced on site due to the hazards of transporting and storing ozone. Ozone oxidation of the contamination is conducted in batch or continuous operations. Note that electrical consumption is high.
- Clays is a technology in which the sorption properties of treated clay are used to capture contaminates from water. The water is passed through clays in a vessel until the clay becomes exhausted. The clay requires disposal.

- Air stripping is the process of bringing about contact between air and water to allow the physical transfer of dissolved molecules from a liquid waste stream to a flowing gas. It is normally carried out as a continuous operation that employs a packed tower. For air stripping, liquid waste is pumped to near the top of the stripping column and flows downward through the tower, cocurrent to an upward air flow. If required, activated carbon can be used to remove contaiminants from the discharged air.
- Ion exchange is a technology by which compounds are removed by the capture of ions on a resinous material known as ion exchange resins. The resin is contained in a column and the wastewater is continuously passed through the column until the resin becomes exhausted, and then is regenerated. Ion exchange is not a destructive technology and the contaminates will require disposal.
- Membrane separation is also called reverse osmosis separation which removes organic molecules from wastewater streams. Wastewater is sent through a reverse osmosis system under pressure. The reverse osmosis system filters, then concentrates waste materials while clean water passes through the membrane.
- Synthetic Carbon is a technology by which compounds are removed by the capture of ions on a resinous material known as Ambersorb®. The resin is contained in a column and the wastewater is continuously passed through the column until the Ambersorb® becomes exhausted, and then is regenerated. This is not a destructive technology and the contaminates will require disposal.

Screening Evaluation

Defined alternatives were evaluated against the short and long-term aspects of three broad criteria: effectiveness, implementability, and cost. Because the purpose of the screening evaluation was to reduce the number of alternatives that

were to undergo a more thorough and extensive analysis, alternatives were evaluated more generally in this phase than during the detailed analysis. However, evaluations at this time were sufficiently detailed to distinguish among the alternatives. In addition, we ensured that the alternatives were compared on an equivalent basis (i.e., definitions of treatment alternatives are approximately at the same level of detail to allow preparation of comparable cost estimates).

Initially, specific technologies or process options were evaluated primarily on the basis of whether or not they could meet a particular remedial action objective. During alternative screening, the entire alternative was evaluated as to its effectiveness, implementability, and cost.

During the detailed analysis, the alternatives were evaluated against nine specific criteria and their individual factors rather than the general criteria used in screening. Therefore, the reader should be familiar with the nine criteria (see Figure 3-3) at the time of screening to better understand the direction that the analysis took. The relationship between the screening criteria and the nine evaluation criteria is conceptually illustrated in Figure 3-3.

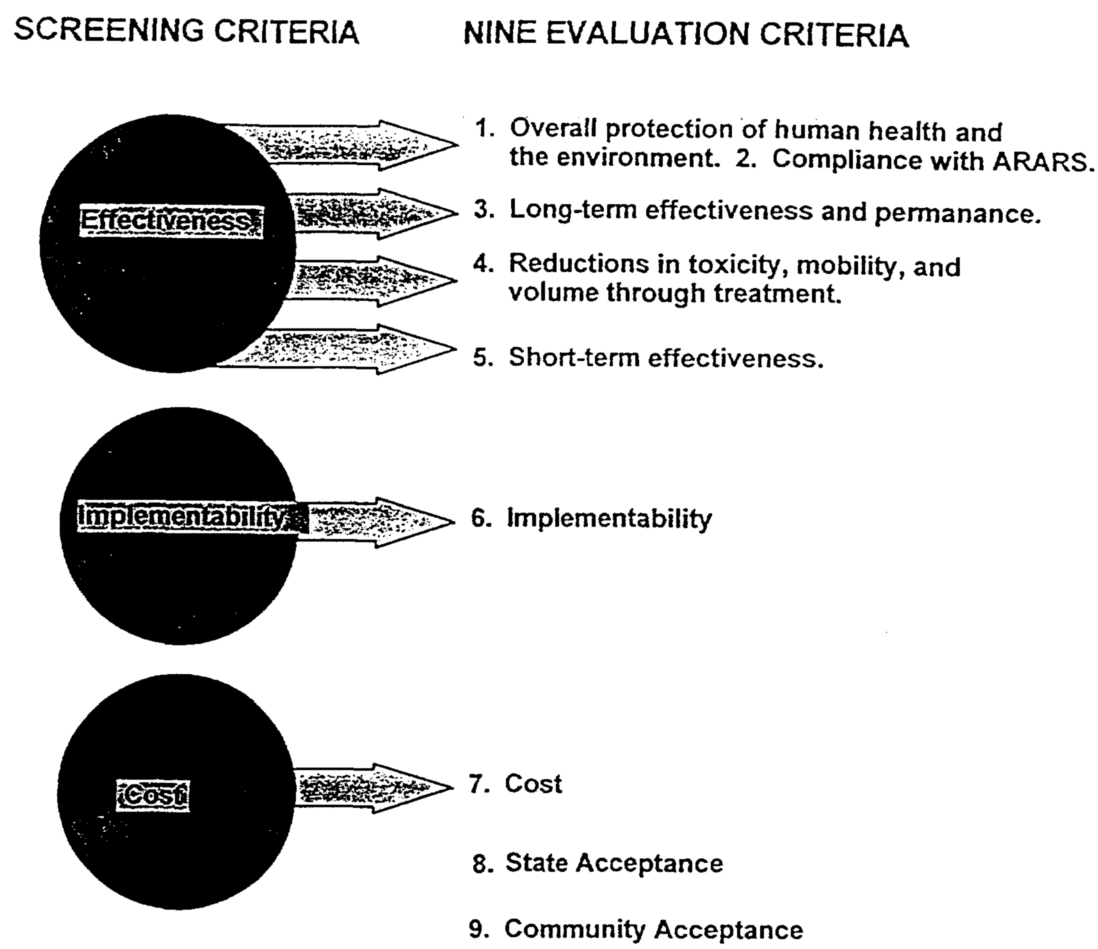
SCREENING CRITERIA
NINE EVALUATION CRITERIA
Effectiveness
1. Overall protection of human health and the environment. 2. Compliance with ARARS.
3. Long-term effectiveness and permanance.
4. Reductions in toxicity, mobility, and volume through treatment.
5. Short-term effectiveness.
Implementability
6. Implementability
Cost
7. Cost
8. State Acceptance
9. Community Acceptance

Figure 3-3

It is also important to note that comparisons during screening were usually made between similar alternatives (the most promising of which was carried forward for further analysis); whereas, comparisons during the detailed analysis were differentiated across the entire range of alternatives. The criteria used for screening are described in the following sections.

Effectiveness Evaluation

A key aspect of the screening evaluation was the effectiveness of each alternative to protecting human health and the environment. Each alternative was evaluated as to its effectiveness in providing protection and the reductions in toxicity, mobility, or volume that it will achieve. Both short and long-term components of effectiveness were evaluated; short-term referring to the construction and implementation period, and long-term referring to the period after the remedial action will be complete. Reduction to toxicity, mobility, or volume refers to changes in one or more characteristics of the hazardous substances or contaminated groundwater by the use of treatment systems that decrease the inherent threats or risks associated with the hazardous chemicals.

Implementability Evaluation

Implementability, as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial treatment system alternative, was used during screening to evaluate the combinations of process options with respect to conditions at a specific site. Technical feasibility refers to the ability to construct, reliably operate, and meet technology-specific regulations for process options until a remedial action is complete; it also includes operation, maintenance, replacement and monitoring of technical components of an alternative, if required, into the future after the remedial action is complete. Administrative feasibility refers to the ability to obtain approvals from AFCEE and agencies, the availability of treatment, storage, and disposal services and

capacity, and the requirements for, and availability of, specific equipment and technical specialists.

The determination that an alternative was not technically feasible or not available precluded it from further consideration unless steps can be taken to change the conditions responsible for the determination. Negative factors affecting administrative feasibility normally involve coordination steps to lessen the negative aspects of the alternative but would not necessarily eliminate an alternative from consideration.

Cost Evaluation

Absolute accuracy of cost estimated during screening was not essential. The focus was to make comparative estimates for treatment alternatives with relative accuracy so that cost decisions among alternatives could be sustained as the accuracy of cost estimates improves beyond the screening process. The procedures used to develop cost estimates for alternative screening were similar to those used for the detailed analysis. The only differences would be in the degree of alternative refinement and in the degree to which cost components were developed.

Cost estimates for screening alternatives typically were based on a variety of cost-estimating data. Bases for screening cost estimates included cost curves, generic unit costs, vendor information, conventional cost-estimating guides, and prior similar estimates as modified by site-specific information.

Both capital and O&M costs were considered, where appropriate, during the screening of treatment alternatives. The evaluation included those O&M costs that will be incurred for as long as necessary, even after the initial treatment action is complete. In addition, potential future remedial treatment costs were

considered to the extent they can be defined. Present worth analyses were used during alternative screening to evaluate expenditures that occur over different time periods.

Recommendation

The review has shown that for the task of removing suspended solid and metals, a Greensand filter is recommended based on operational, maintenance and reliability.

The recommended approach for removing toxic organic compounds is to use a UV/peroxide system to partially oxidize and remove the compounds. To polish the effluent to levels below the detection limits, activated carbon is recommended.

A synthetic carbon (Ambersorb) could be used as an alternate to the UV/peroxide-activated carbon system. This process requires less space, is faster reacting, does not produce fines, is regeneratable on-site and is not biologically fouled.

GROUND WATER GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS*
COLLECTION	EXTRACTION	EXTRACTION WELLS	SERIES OF WELLS TO EXTRACT CONTAMINATED GROUND WATER	POTENTIALLY APPLICABLE
		EXTRACTION/INJECTION WELLS	INJECTION WELLS INJECT UNCONTAMINATED WATER TO INCREASE FLOW TO EXTRACTION WELLS	POTENTIALLY APPLICABLE
	SUBSURFACE DRAINS	INTERCEPTOR TRENCHES	FRENCH DRAINS CONSTRUCTED TO CAPTURE GROUND WATER	NOT FEASIBLE BECAUSE OF LOOSE SOIL
TREATMENT	BIOLOGICAL TREATMENT	AEROBIC	DEGRADATION OF ORGANICS USING MICROORGANISMS IN AN AEROBIC ENVIRONMENT	NOT APPLICABLE TO INORGANIC CONTAMINANTS PLUS ORGANIC CONCENTRATIONS ARE TOO LOW
		ANAEROBIC	DEGRADATION OF ORGANICS USING MICROORGANISMS IN AN ANAEROBIC ENVIRONMENT	NOT APPLICABLE TO INORGANIC CONTAMINANTS PLUS ORGANIC CONCENTRATIONS ARE TOO LOW
	PHYSICAL/CHEMICAL TREATMENT	PRECIPITATION	ALTERATION OF CHEMICAL EQUILIBRA TO REDUCE SOLUBILITY OF THE CONTAMINANTS	POTENTIALLY APPLICABLE
		AIR STRIPPING	MIXING LARGE VOLUMES OF AIR WITH WATER IN A PACKED COLUMN TO PROMOTE TRANSFER OF VOC'S TO AIR	POTENTIALLY APPLICABLE
		CARBON ADSORPTION	ABSORPTION OF CONTAMINANTS ONTO ACTIVATED CARBON BY PASSING WATER THROUGH CARBON COLUMN	POTENTIALLY APPLICABLE
		REVERSE OSMOSIS	USE OF HIGH PRESSURE TO FORCE WATER THROUGH A MEMBRANE LEAVING CONTAMINANTS BEHIND	POTENTIALLY APPLICABLE
		ION EXCHANGE	CONTAMINATED WATER IS PASSED THROUGH A RESIN BED WHERE IONS ARE EXCHANGED BETWEEN RESIN AND WATER	POTENTIALLY APPLICABLE
		ULTRAVIOLET OXIDATION	CHEMICAL REACTIONS CAUSE CONTAMINANTS TO OXIDIZE THE ADDITION OF OXYGEN BREAKS DOWN ORGANIC WASTE OR CHEMICALS SUCH AS BENZENE, PHENOLS AND ORGANIC SULFUR COMPOUNDS	POTENTIALLY APPLICABLE
		OZONATION	OZONE IS PRODUCED WITH A CORONA DISCHARGE TECHNOLOGY THIS OXIDIZES THE CONTAMINANTS	POTENTIALLY APPLICABLE
		CLAYS	ABSORPTION OF CONTAMINANTS BY CHEMICALLY TREATED CLAYS BY PASSING WATER THROUGH VESSEL WITH CLAY IN IT	POTENTIALLY APPLICABLE
		SYNTHETIC CARBON	RESIN CARBON REMOVES CONTAMINANTS BY ABSORPTION. THE RESIN IS IN A COLUMN VESSEL AND WATER IS PASSED OVER IT	POTENTIALLY APPLICABLE
	IN SITU TREATMENT	BIORECLAMATION	SYSTEM OF INJECTION AND EXTRACTION WELLS INTRODUCE BACTERIA AND NUTRIENTS TO DEGRADE CONTAMINATION	NOT FEASIBLE BECAUSE IT DOES NOT ACHIEVE CONTAINMENT
		AERATION	SYSTEM OF WELLS TO INJECT AIR INTO GROUND WATER TO REMOVE VOLATILES BY AIR STRIPPING	NOT FEASIBLE BECAUSE IT IS NOT ACCEPTABLE TO THE PUBLIC
		PERMEABLE TREATMENT BEDS	DOWNGRADIENT TRENCHES BACKFILLED WITH ACTIVATED CARBON TO REMOVE CONTAMINANTS FROM WATER	NOT FEASIBLE BECAUSE OF DEPTH OF LOOSE FILL
		CHEMICAL REACTION	SYSTEM OF INJECTION WELLS TO INJECT OXIDIZER SUCH AS HYDROGEN PEROXIDE TO DEGRADE CONTAMINANTS	NOT FEASIBLE BECAUSE NOT ALL CONTAMINANTS ARE BIODEGRADABLE
DISCHARGE	ONSITE DISCHARGE	INJECTION WELLS	INJECTION WELLS INJECT UNCONTAMINATED WATER TO MAINTAIN WATER BALANCE	POTENTIALLY APPLICABLE
	OFFSITE DISCHARGE	POTW	LOCAL POTW NOT ABLE TO HANDLE VOLUME AND CHEMISTRY	NOT FEASIBLE BECAUSE OF VOLUME OF WATER
		DEEP WELL INJECTION	SHALLOW BED ROCK OF GRANITE PREVENTS DEEP WELLS	NOT FEASIBLE BECAUSE DEEP AQUIFIER NOT SUITABLE FOR INJECTION OF CONTAMINATED WATER
		PIPELINE TO BAY	DISCHARGE TO BAY	NOT FEASIBLE WOULD UPSET FRESH TO SALTWATER BALANCE

LEGEND [hatched box] - TECHNOLOGIES THAT ARE SCREENED OUT

* SCREENING COMMENTS MAY NOT BE APPLICABLE TO ACTUAL SITE

MK	REVISION	BY	CHK	DATE	MK	REVISION	BY	CHK	DATE

DRAWN DATE
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APPROVED:
APPROVED:

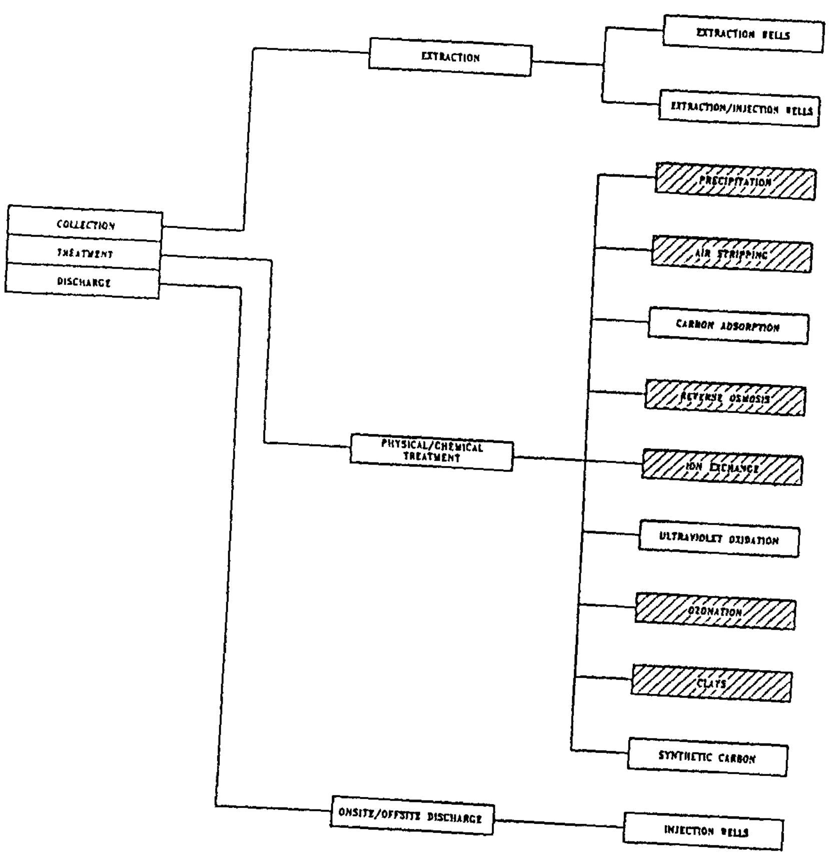
Jacobs Engineering Group Inc.
Central Region 35-K784-00 Houston, Texas

CONTRACT NO	DWG NO	REV	SCALE
F41624-94-D-8115-0025	FIGURE 3.4	A	NONE

DWG TITLE
MMR PLUME RESPONSE PROJECT
PROCESS TREATMENT FACILITY
SCREENING PROCESS

FILE INFO: C:\MMR\PROC2 1=1.0 10/10/1996 07:51 KN PC-#0975

GROUND WATER DETAILED RESPONSE ACTIONS / REMEDIAL TECHNOLOGY / PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	COST



PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	COST
EXTRACTION WELLS	EFFECTIVE AND RELIABLE	EASILY IMPLEMENTED. RESTRICTIONS ON FUTURE LAND USE. PERMIT REQUIRED	MODERATE CAPITAL, MODERATE MAINTENANCE
EXTRACTION/INJECTION WELLS	EFFECTIVE AND RELIABLE	EASILY IMPLEMENTED. RESTRICTIONS ON FUTURE LAND USE. PERMIT REQUIRED	MODERATE CAPITAL, MODERATE MAINTENANCE
PRECIPITATION	EFFECTIVE AND RELIABLE. CONVENTIONAL TECHNOLOGY. REQUIRES SLUDGE DISPOSAL	READILY IMPLEMENTABLE	HIGH CAPITAL, HIGH OPERATIONS & MAINT
AIR STRIPPING	EFFECTIVENESS AND RELIABILITY REQUIRE PILOT TEST TO DETERMINE	NOT ACCEPTABLE TO PUBLIC/LOCAL GOVERNMENT. PERMIT REQUIRED	HIGH CAPITAL, LOW OPERATIONS & MAINT
CARBON ADSORPTION	EFFECTIVENESS AND RELIABILITY REQUIRE PILOT TEST TO DETERMINE	READILY IMPLEMENTABLE	MODERATE CAPITAL, POSSIBLE HIGH OPERATIONS & MAINT
REVERSE OSMOSIS	EFFECTIVE AND RELIABLE, HIGH ENERGY USAGE	READILY IMPLEMENTABLE	HIGH CAPITAL, HIGH OPERATIONS & MAINT
ION EXCHANGE	EFFECTIVE AND RELIABLE, HIGH CHEMICAL USAGE. PROPER PRETREATMENT REQUIRED	READILY IMPLEMENTABLE	HIGH CAPITAL, HIGH MAINTENANCE
ULTRAVIOLET OXIDATION	EFFECTIVE AND RELIABLE. REMOVE 90%-95% OF ORGANIC CONTAMINANTS. REQUIRES POLISHING TECHNOLOGY	READILY IMPLEMENTABLE	MODERATE CAPITAL, HIGH MAINTENANCE
OZONATION	EFFECTIVE AND RELIABLE	READILY IMPLEMENTABLE, PROPER PRETREATMENT AND POSTTREATMENT REQUIRED	HIGH CAPITAL, HIGH MAINTENANCE
CLAYS	EFFECTIVE AND RELIABLE. REQUIRES SLUDGE DISPOSAL	READILY IMPLEMENTABLE, PROPER PRETREATMENT REQUIRED	MODERATE CAPITAL, HIGH OPERATIONS & MAINT
SYNTHETIC CARBON	EFFECTIVE AND RELIABLE. REQUIRES WASTE DISPOSAL	READILY IMPLEMENTABLE	MODERATE CAPITAL, LOW OPERATIONS & MAINT
INJECTION WELLS	EFFECTIVE AND RELIABLE	EASILY IMPLEMENTABLE; NOTIFICATION FOR PERMIT REQUIRED	MODERATE CAPITAL, MODERATE MAINTENANCE

LEGEND

(hatched) - TECHNOLOGIES THAT ARE SCREENED OUT

* SCREENING COMMENTS MAY NOT BE APPLICABLE TO ACTUAL SIZE.

MK	REVISION	BY	CHK	DATE	MK	REVISION	BY	CHK	DATE	
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										APPROVED
										APPROVED

JE Jacobs Engineering Group Inc.
Central Region 35-K784-00 Houston, Texas

CONTRACT NO	DWG NO	REV	SCALE
F41624-94-D-8115-0025	FIGURE 3-5	A	NONE

DWG TITLE
MMR PLUME RESPONSE PROJECT
PROCESS TREATMENT FACILITY
SCREENING PROCESS

FILE INFO: C:\MMR\PROC3 1=1.0 10/10/1996 07:52 KN PC-#0975

4.0 DESCRIPTION AND LAYOUT FOR KEY SYSTEM COMPONENTS

4.1. TREATMENT SYSTEM DESIGN DETAILS

This section provides more details on the sizing of the individual items in the treatment train. Refer to Section 3.1 for a description of the FS-12 process, and Volume II for copies of the Process Flow Diagram (PFD) and the Process and Instrument Diagrams (P&ID). Overall, the treatment capacity of the system is as follows:

- Average expected flow = 828 gpm (per the OpTech groundwater modeling)
- Design flow = 1015 gpm (a 20% safety factor over the OpTech modeling)
- Maximum flow = 1260 gpm (an additional 25% over the design flow)

In addition to the built-in extra capacity, space has been left in the treatment building for the installation of additional treatment equipment that will provide an additional 30% increase in capacity, total of 1640 gpm which is 100% more than the flow rate modeled by OpTech.

The sizing basis for the extraction and reinjection wells is described in Section 5.0, Rationale and Description for Extraction and Reinjection Systems. The sizing basis for the individual equipment in the treatment system is described in the following paragraphs.

4.1.1 Influent Holding Tank (1T-101)

The influent holding tank is designed for a five minute holdup of the incoming design flow of 1015 gpm, plus backflush from the Greensand filters or the sand filters. The backflush volume provided is 1140 gpm for 10 to 15 minutes (17,000 gallons). The total volume provided is 23,000 gpm.

pH control is provided at the influent tank. The incoming pH is expected to be between 5.3 and 6.5, with the average expected to be below 6. pH adjustment to the 6.5 to 8.5 range may be required for iron and manganese removal. Therefore, the pH control system has been designed to control the pH between 6.5 and 8.5. The groundwater is only lightly buffered, so a feed-forward system is used to smooth out pH variations. The influent tank is agitated using a recirculating loop with the pH measured in the tank as a fine adjustment to the feed-forward loop. Caustic is added to the system from a storage tank using metering pumps. The caustic addition rate is expected to be about 30 gallons/day, so the 4500 gallon caustic tank will hold about a five month supply. The storage tank is sized to hold the contents of a 4000 gallon caustic truck.

4.1.2 Greensand Filter System

Potassium permanganate is used to convert the iron and manganese from soluble to insoluble forms. The permanganate oxidizes the metals to precipitate them from solution. The Greensand filters provide the following functions:

- The Greensand holds permanganate on its surface to protect against over feeding or underfeeding of the permanganate. If excess permanganate is added, the Greensand removes the excess from the water. If too little permanganate is added, the permanganate absorbed on the Greensand oxidizes any excess iron and manganese.
- The Greensand works as a filter to remove any suspended solids (TSS) from the influent, and to filter out the precipitated metals.

The Greensand filters were not piloted because they represent a common technology that has been proven in hundreds of applications around the country. The Greensand filters for this application were sized based on the following criteria:

- A maximum flow rate per filter of 5 gpm/ft^2 with one filter on standby for backwash.

- A maximum backwash frequency of once/day per filter, or a maximum of one filter being backwashed each shift.

The RFP issued to obtained filter bids lists the above items as a duty specification.

The potassium permanganate will be received, as crystals, in 25 kg bags and will be dissolved in water prior to use. The estimated addition rate of potassium permanganate is 0.6 lbs/hr, so a 25 kg bag will last almost four days. The mixing tank is sized to hold two batches as insurance against running out of permanganate.

4.1.3 Greensand Filter Backwash System

The backwash system is designed to handle one backwash every eight hours at a rate of 1140 gpm for 10 to 15 minutes. The system is also designed to hold up to two weeks of solids removed during the backwash, so that once every two weeks a 3000 gallon truck can be loaded to haul the sludge to disposal. The sludge is not expected to be a hazardous waste. The concentration of organics in the sludge is the same as the concentration in the groundwater plume (micrograms/l range). The sludge will be a good flocullant, so it is assumed that the sludge can be sent to a wastewater treatment system that can take advantage of the flocullant characteristics.

The backwash is sent to a sedimentation tank, 1T-103, which is sized to hold the entire backwash volume, up to 17,000 gallons. The backwash is allowed to settle and the clear water is then decanted back to the influent tank using pumps designed to automatically start after a three hour settling time. The sludge is allowed to accumulate in the cone of the tank. The incoming flow from each batch will be used to agitate the sludge to prevent it from setting up. As an additional protection, process water is piped to the outlet line to allow backflushing the tank.

The truck load-out is located inside the treatment building, on the concrete pad which will hold the entire volume of the tank or the truck.

4.1.4 UV/Peroxide System

The treatment system can meet all the required removal efficiencies without the UV/peroxide system. The Greensand filters will remove the iron and manganese and the activated carbon can remove all the metals. However, it is economical to operate the UV/peroxide system to reduce the load on the activated carbon system and thus reduce carbon consumption and operating costs.

The size of the UV/peroxide system is based on pilot tests conducted by Solarchem, see Section 3.3 for a discussion of the pilot plant tests. The results of the pilot tests were used to design a UV/Peroxide system for 90% removal of the benzene in the system with a small removal of EDB. The UV/Peroxide system is not efficient in removing EDB.

The pilot plant tests demonstrated that a power input of 2.7 kw/1000 gallons of water is required to remove 90% of the benzene. For a flow rate of 1015 gpm, this is equivalent to a power input of 164 kw. The next largest size unit is 180 kw, or six 30 kw units. The maximum flow through any single unit is 450 gpm, so the system has been designed for three parallel trains of two units in series per train. The flow rate/train will be 338 gpm. The system will handle up to 1350 gpm, if required in the future, but with a loss in benzene removal efficiency.

35% hydrogen peroxide will be fed upstream of the UV system. The peroxide will be added from carboys using a metering pump. The system is designed to provide a peroxide concentration of 15 ppm in the feed to the UV reactors. This is in excess of the amount required to oxidize to organics. Peroxide that is not consumed will be removed by the carbon filters. Since peroxide is unstable it will

slowly decompose to water and oxygen in the carbon filters. Activated carbon has a strong affinity for oxygen, so the carbon will adsorb the released oxygen, plus will adsorb any dissolved oxygen that enters in the influent water.

4.1.5 Activated Carbon Units

Pilot tests were conducted using water from the FS-12 plume that contained 1800 ppb benzene and 300 ppb EDB. The pilot tests demonstrated that even these high contaminant concentrations can be treated to non-detect levels using a contact time of 4.5 minutes in an activated carbon system. However, instead of a contact time of 4.5 minutes, the units have been sized for a normal contact time of 15 minutes with a minimum contact time of around 10 minutes. The 15 minutes is based on tests conducted in Florida, on EDB contaminated groundwater, that demonstrated that a 15 minute residence time allows efficient use of the carbon - the tests demonstrated that 50% saturation of the carbon can be achieved at the 15 minute residence time.

20,000 pound carbon beds will be used, which is the largest standard size units. The 20,000 pound size is based on the capacity of the trucks used to deliver the carbon.

The system is designed so that there will always be two carbon beds in series. The system is designed for three parallel trains of two beds in series per train. It is estimated that a carbon bed will need to be regenerated about once every 1-1/2 months, eight beds/year. Whenever a bed is removed from service for regeneration, the entire train containing that bed will be removed from service. The entire flow will be handled by the two remaining trains at a residence time of about 10 minutes in each bed or 20 minutes total for a train of two beds in series. To ensure that multiple beds will not require replacement at the same time, startup of the beds will be staggered. However, in the unlikely event that two beds must

be replaced at the same time the flow rate to the system will be decreased for the 3 to 4 hours required to replace the carbon.

Space is provided for a possible future fourth train of two carbon beds in series. If the fourth train is installed, the system will be capable of handling a flow rate of 1350 gpm, at a residence time of 15 minutes or 2025 gpm at a residence time of 10 minutes.

Space is provided to bring in trucks to remove the spent carbon and to bring in fresh carbon. The truck spot is located inside the building, on the concrete pad which will contain the volume of the truck. Process water will be used to slurry the spent carbon out of the carbon filters and to slurry fresh carbon from the trucks to the filters. Air is provided to provide pressure on the filters and on the truck to aid in the transfer.

4.1.6 Effluent Tank (1T-102)

The effluent tank is sized to provide a five minute holdup of the 1015 gpm flow to the reinjection wells, plus hold up to 17,000 gallons of water to be used for backflushing both the Greensand filters and the carbon filters. The tank has a total capacity of 23,000 gallons.

The effluent from this tank is also piped up to provide water for use in the treatment facility: This water has been treated to remove the iron and manganese and to remove the toxic organic compounds to below the detection limit, and thus represents a very high purity water source.

- Process water is provided to dissolve the potassium permanganate, to provide water to slurry the carbon in and out of the filters, and for other miscellaneous uses.
- Part of the water is chlorinated to provide water for services that require the use of water that has a potable water permit, such as toilets and safety

showers, but will not be consumed by personnel at the site. Bottled water will be provided for human consumption.

4.1.7 Treated Water Reinjection

Metering pumps are provided to add hydrogen peroxide and sodium hypochlorite to the treated water before it is sent to the reinjection wells.

The hydrogen peroxide is provided to add dissolved oxygen back into the water. All the dissolved oxygen will be removed from the water in the UV/peroxide system, which consumes oxygen, and the carbon system, which adsorbs oxygen. The system is designed to maintain a dissolved oxygen (D.O.) concentration of 8 ppm. Hydrogen peroxide is unstable and will slowly decompose in the groundwater to release oxygen.

The sodium hypochlorite is provided if it is required to reduce biological activity around the reinjection wells. The addition of D.O. to the reinjection water will generate the potential for biological growth around the well screens, if the water mixes with any groundwater containing naturally occurring organic compounds. If biological plugging of the reinjection wells is occurring, the hypochlorite can be fed either continuously or periodically to kill the bacteria. The hypochlorite is highly reactive, so it will quickly decompose in the groundwater and will not reach any surface water bodies.

4.2 TREATMENT SYSTEM CONTROL PHILOSOPHY

The FS-12 system is designed to normally operate unmanned. The control signals will be sent to the SD-5 treatment building, where operators will normally be on duty. Both the wells and the FS-12 treatment system will be on automatic control.

If an upset condition occurs, alarms will warn the operators at SD-5 that action is required at FS-12. Most of the upset conditions can be solved using the controls provided at SD-5 such as changing the set points on flow meters, or starting and

stopping pumps. However, if the problem can not be solved from SD-5, operators will drive to FS-12.

On-site operator attention is only required every three days to replenish reagents, such as potassium permanganate and hydrogen peroxide.

The components of the control systems are shown on the PFDs and P&IDs, contained in Volume II. The following is a summary of the major control features:

- The pumping rate from each of the extraction wells is on flow control. This is one of the most important control variables. Monitoring wells will be used to measure the groundwater levels and the concentrations of contaminants in the plume to insure that the extraction rates are meeting the plume containment goals. The flow rate from each well will be adjusted to achieve the containment goals.
- The flow rate from the influent tank (1T-101) through the individual Greensand filters is also on flow control. The pressure drop through each of the Greensand filters will vary significantly, depending on the time since the last backwash, so the flow control is needed to balance the flow between the filters.
- The level in 1T-101 will be allowed to vary. This capability is needed to allow the volume to vary depending on the backwash cycle.
- A high level alarm is provided on 1T-101 to warn the operator that the flow rates need to be rebalanced. If the level in the tank continuous to rise, a second high level alarm will shut off the flow from the extraction wells.
- The pH of the water in the influent tank is controlled to optimize the removal of iron and manganese. The pH of the incoming water is expected to be below 6.0, and will be adjusted to 6.5 to 8.5, if required, to improve the metals

removal. The pH is adjusted by adding caustic to the tank, using a recirculating loop to mix the tank.

- Potassium permanganate is added as a ratio of the flow to the Greensand filters. The ratio will be adjusted to match changes in the iron and manganese concentrations.
- The controls automatically backwash the Greensand filters when the pressure drop across a filter reaches 10 psi. The backwash rate is on flow control to maintain a backwash loading of 12 gpm/ft^2.
- The backwash from the Greensand filters is allowed to settle in the sedimentation tank (1T-103). After three hours of settling, the recirculating pump automatically starts and pumps the decanted water back to 1T-101.
- The removal of the sludge from 1T-103 will be manually performed. When the cone bottom of the tank is full, a truck will be called-in to haul the sludge to disposal.
- Hydrogen peroxide is added to the system using metering pumps. The pumping rate can be manually adjusted to maintain the optimum peroxide concentration in the feed to the UV/peroxide system. Initially, the peroxide rate will be set to maintain a concentration of 15 ppm, but will be adjusted with time to optimize the performance of the system. Performance will be determined by sampling the UV/peroxide discharge and analyzing for the concentration of organic compounds.
- The flow rate to the individual UV/peroxide trains is manually adjusted. The pressure drop is low, and does not change with time, so manual adjustment will be satisfactory.
- The UV/peroxide has a number of safety controls that shut off parts of the system in the event of the failure of a key component. A train will be shut down and blocked in if a leak occurs in any of the lamps in the train. Power to an individual UV lamp will be shut off if any of the following occur:
  - The power door is left open

- The cover of the unit is left open
- High temperature in the reactor
- High temperature in the lamp
- Failure of the wiper that cleans the lamp.
- Failure of the lamp

- If power to a lamp is shut off, flow will continue through the train, but with a reduced organic destruction because the power will only be to one lamp in the train. The activated carbon will remove the additional organics, so there will be no increase in the concentration of contaminants in the reinjection water. However, the operator will be instructed to correct the problem and reenergize the failed lamp as quickly as possible to minimize carbon consumption.
- Operation of the carbon filters is on manual control. Manual valves will be used to balance the flow rate between the carbon trains, the suspended solids have been removed upstream in the Greensand filters so plugging is not expected to be a problem and the manual flow adjustments are expected to be infrequent. High differential pressure alarms will warn the operator if a carbon bed is being plugged. Samples will be collected and analyzed from between the first and second bed in each train to monitor when the carbon in the first bed is becoming exhausted. When toxic organic compounds are detected in the outlet from the first bed, the carbon in that bed will be replaced and the order of the beds will be swapped. The bed with the fresh carbon will move to the second position. During the period when the carbon is being replaced, the entire train with the replacement will be isolated from the flow to insure that the flow never passes through just one carbon bed in series. During this period, the flow rate will increase through the other two beds to handle the total flow.
- The effluent holding tank (1T-102) is sized to provide a five minute holdup on the flow rate to the reinjection wells plus 17,000 gallons of water to be used as backwash. The flow rate into the tank is set by the flow control valves at the

Greensand filters. The flow out of the tank is set by the flow control valves at the individual reinjection wells. A level indicator allows the operator to monitor the level in the tank. Level alarms warn the operator that action may be required to rebalance the flow rates. A second high level alarm shuts off the influent pumps before the tank would overflow.

- The addition of hydrogen peroxide, to replace the dissolved oxygen in the reinjected water, is ratioed to the reinjection water flow rate to maintain a dissolved oxygen concentration of 8 ppm.
- The flow rate to each reinjection well is on flow control, which can be adjusted remotely from the SD-5 control room. The level in the well is monitored in addition to the pressure of the reinjection water. The level and pressure both provide an indication of any fouling that will restrict flow into the well. The flow rate to each reinjection well will be adjusted periodically based on feedback from the levels in the monitoring wells, to insure that the reinjection aids the goal of capturing the plume without significantly impacting the groundwater levels in the area.

4.3 TREATMENT SYSTEM CONTAINMENT

The concentration of contaminants in the groundwater are significantly below the hazardous waste trigger levels, per the TCLP. However, as insurance against spills or leaks returning contaminated groundwater to the aquifer, containment has been provided both for the influent line from the extraction wells and for the treatment system.

Double walled piping will be used to contain any leaks in the underground piping between the extraction wells and the treatment system (see Section 4.0 for a more detailed description).

The treatment area has been designed with full spill containment and secondary containment, to contain any spills or leaks from the system. The following containment features have been provided in the design:

- The entire treatment system is installed on a concrete pad that is sloped toward collection trenches and a collection sump. The pad has a one-inch lip around the edge to direct any spills toward the trenches and the sump. The entire containment volume is:

Sloped concrete pad	11,313 gallons
Trenches	11,512
Sump	942
TOTAL	23,767 gallons (vs largest tank volume of 23,000 gallons)

- Water stops will be installed in all the joints in the concrete to seal the joints.
- The tanks and treatment equipment are all elevated or installed on concrete foundations that will allow the visible detection of leaks and will contain any leaks so that the leak does not reach the groundwater.
- A high level alarm is installed in the sump to warn the operator that a leak or spill has occurred. If the level in the sump continues to rise, a high-high alarm will sound and will shut off the flow from the extraction wells.

5.0 EXTRACTION AND REINJECTION SYSTEMS

5.1 EXTRACTION WELL DETAILS

The locations, depths, screening depths, and pumping rates for the FS-12 extraction wells are based on Scenario 15 of OpTech's FS-12 modeling report.

To be conservative and to allow for possible future expansions in pumping rates, the following allowances have been made in the design of the extraction system:

- Monitoring wells will be installed in the ETR areas that will allow evaluation of the effectiveness of the plume capture. Information from this monitoring of the water levels and contaminent concentrations in these wells will be used to insure that system operation is meeting the plume containment goals.
- The design flow rate includes a 20% safety factor over the modeled flow rate from each individual well.
- Groundwater modeling indicates that the plume drawdown is less than 1-foot. The minimum water level under drought conditions is 55-feet above MSL.
- The main piping header is designed to initially operate with low flows from the wells allowing for future expansion in pumping rates and/or additional wells.
- Control valves have been provided that utilize 20% of the total system pressure drop. If these control valves are allowed to operate full open, the flow rate from each individual well can be increased by 30%.
- Isolation valves and blind flanges on the end of the headers are being installed in the extraction well header to allow the future installation of additional wells without taking the full system out of service.
- The well casings have a large enough diameter that larger pumps can be installed in the future, if needed, to significantly increase the flow from any of the wells. The electrical supply to each well is large enough that the capacity of any individual pump can be more than doubled in the future.

The following controls are provided at each of the extraction wells:

- The flow rate from each well is automatically controlled by flow control valves. This flow will be adjusted, based on information obtained from the monitoring wells to insure that the plume containment goals are being achieved.
- The water level in each well is indicated in the control room to allow the operator to monitor the level in the plume and/or as an indication of plugging of the well screens.
- A low level cutoff is provided to protect the pump against excessive drawdown.

An air/vacuum release valve is provided that will allow the piping to drain during a shutdown and will allow the release of air during startup.

5.2 EXTRACTION PIPING CONTAINMENT

Full secondary containment is provided for both the piping inside the well vaults and for the underground piping between the vaults and the treatment system. Leak detection is provided immediately to warn the operator that a leak or spill has occurred. This is done through remote monitoring of the line. This information combined with the flow rate information available to the operator, will allow the operator to take immediate action, if required, to minimize the impact of any spill.

Containment inside the vaults is provided by the floor of the vaults. High level alarms are provided in the vaults to warn the operator of any leaks or spills.

Double-walled piping is used for the underground extracted water lines. The inner pipe contains the extracted water and the outer pipe will contain any leaks in the inner pipe. A continuous tape will be installed between the inner and outer pipes to detect any leaks. This leak detection tape has the following characteristics:

- If a leak occurs, the tape will detect the leak and will sound an alarm that will immediately warn the operator.
- The leak detection logic system will then record the exact location of the leak to minimize the excavation required to find and correct the leak.

The combination of the leak detection system with the influent flow meters will also allow the operator to take action in the unlikely event of a rupture of both the inner and outer pipes. The leak detection tape will warn the operator that a leak has occurred. The operator will then check the meter that indicates the flow rate into the treatment system. If the flow rate has dropped significantly, the operator will know that a major failure has occurred and can shut off the flow from the wells.

5.3 REINJECTION WELL DETAILS

The design basis location, depths, screen depths, and flow rates for the reinjection wells are based on Scenario 15 of OpTech's groundwater modeling with a 20% safety factor added to the flow rates. However, the flow rate into any individual well is limited only by potential plugging in the sand pack around the well and the head pressure exerted by the pumps.

Using the design basis of allowing a maximum 0.1 foot/second velocity through the wellscreens, the eight-inch reinjection well screens, 60 feet long, would have a capacity to handle a reinjection rate of 5600 gpm. This is far in excess of the 10 to 70 gpm needed. This calculation is supported by short-term reinjection tests which demonstrated, that without plugging, the water will gravity flow back into the wells.

However, some degree of plugging will occur in the reinjection wells, so the following provisions have been made to offset the plugging impact:

- The reinjection wells have been specified to be the same diameter as the extraction wells (8 inches).
- The effluent pumps, at the treatment system, have been designed to provide a minimum of 25 psig pressure at each well in case pressure is required to force the water into the groundwater formation.
- Hypochlorite injection facilities have been provided at the treatment system to allow the continuous or periodic addition of chlorine to reduce biological activity.

In addition to the above provisions provided to minimize the plugging impact, additional provisions have been made to provide flexibility into the reinjection system:

- The reinjection well header is designed to operate at low flows allowing for future expansion in flow rates or additional wells.
- Control valves have been provided that utilize 20% of the system pressure drop. If the control valves are allowed to operate wide open, the flow rate to all the wells can be increased by 25%.
- Isolation valves have been provided in the reinjection well header, plus blind flanges have been provided at strategic points on the header, to allow the future installation of additional wells without taking the entire header out of service.

The following controls are provided at each of the reinjection wells:

- The flow rate into each reinjection well is automatically controlled. This flow rate can be adjusted from the control room, based on information obtained from the monitoring wells, to insure that the reinjection wells are accomplishing their goals of balancing the groundwater levels.

- The pressure and level in each of the wells will be continuously indicated in the control room. These signals will provide the operator information on any plugging in each well.

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6.0 OPERATIONAL PHILOSOPHY AND SAFEGUARDS

6.1 PERFORMANCE MONITORING NETWORK

The purpose of the Performance Monitoring Evaluation (PME) system are to:

- Determine if the extraction, treatment, reinjection (ETR) system is meeting performance criteria, specifically including both the hydraulic capture and chemical remediation of the Fuel Spill (FS-12) plume located north of Snake Pond.
- Coordinate ETR performance monitoring with concurrent monitoring being conducted as part of the ecological monitoring program, the sitewide inorganic investigation, and the ETR System Design Operations and Maintenance (O&M) Plan.
- Collect time-series data using the observational approach, as appropriate, to optimize plume capture.

The PME is based on know aquifer characteristics, the 3-D groundwater model, and professional judgment. It will include horizontal and vertical monitoring of the contaminant plume and groundwater hydraulics system, treatment system monitoring, and compliance monitoring. A detailed PME Plan will be provided as part of the Final Design Package.

6.2 OPERATIONS AND MAINTENANCE

6.2.1 Manning Basis/Frequency

The treatment facility will be unmanned. Regular surveillance will be performed during normal operations and personnel dispatched only in the event of an upset condition or other trouble alarm.

6.2.2 Sampling Program

The plant will meet the effluent discharge limits listed in Table 2-5 for injection. The procedures for collecting samples and the methods for sampling will be in accordance with the HQ AFCEE QAPP. The numbers and frequency of sample collection will be included in the Final Design Package.:

All injection samples will be grab samples, composited for analysis unless otherwise specified. All other extraction and treatment samples will be grab samples.

6.2.3 Raw Material Receipt

Chemicals will be used for a variety of purposes in water treatment. These are oxidation, disinfection, organic removal, and pH adjustment.

Chemicals used at water treatment plants will meet the applicable standards of the AWWA. The AWWA publication number for these standards are:

Category	AWWA Standard	Chemical Name
Hypochlorite	B-300	Sodium hypochlorite (hypochlorites)
pH	B-501	Caustic soda
Oxidant	B-603	Potassium permanganate
Organics	B-604	Granular activated carbon

The selection of methods of chemical handling and storage were based primarily on ease of operation, operating flexibility, and safety considerations. Chemicals will be received in shipping containers such as bags, boxes, drums, or canisters. Equipment used for chemical handling will include carts, dollies, fork lifts, etc. If chemicals are shipped in bulk quantities, the mode of unloading depends on the physical characteristics of the chemical. Bulk liquids, such as caustic, will be

unloaded by pumping from the truck to the tank at the treatment plant. Chemicals shipped in bags, drums, barrels, or other shipping containers will be stored by placing these containers in a specific storage area. Hazardous chemicals will be stored in separate rooms to avoid reaction of chemical vapors.

Chemical solutions will be applied directly, or after dilution, to the water being treated by volumetric liquid feeders such as metering pumps. Rapid, thorough mixing of the chemical solution will be provided.

6.2.4 Greensand Treatment

The manganese Greensand treatment system will be regenerated with potassium permanganate ($KMnO_4$) on a continuous basis. The system will operate as a standard pressure filter system. The $KMnO_4$, without chlorine, can be estimated as follows:

$$\begin{aligned} \text{mg/l } KMnO_4 &= (1 \times \text{mg/l Fe}) + (2 \times \text{mg/l Mn}) \\ &= 1 \times 0.526 + 2 \times 0.065 \\ &= 0.526 \times 0.130 \\ &= 0.656 \text{ mg/l} \end{aligned}$$

The backwash flow rate will be sufficient to produce a 40% bed expansion. The normal flow rate will be 1140 gpm for a 12' diameter vessel or 12 gpm/ft.^{2}.

The Greensand treatment will be backwashed when the pressure drop reaches 10 psi. After each service cycle the manganese Greensand will be backwashed for 10 - 15 minutes to remove suspended material collected during the seine. The manganese Greensand will be expanded a minimum of 35% during backwash.

6.2.5 UV/Oxidation

The UV/oxidation is a method of destroying hazardous organic compounds present in contaminated waters. UV/oxidation involves the addition of oxidizing

agents, such as ozone or hydrogen peroxide and irradiating the resulting solution with a powerful ultraviolet lamp. The photolysis produces highly reactive radicals, such as the hydroxyl radical (OH), which initiate a rapid cascade of oxidative reactions. If taken to completion, the end products are mainly carbon dioxide and water.

When there is water flow into the system hydrogen peroxide will be added. The hydrogen peroxide is added into the line at an injection port and mixed with the water by a pump and a static mixer. The flow rate of the reagent will be controlled by the metering pump.

Water enters at the bottom of the reactor and flows up in a turbulent plug flow pattern for efficient destruction of contaminants. A UV lamp situated at the center of the reactor, emits ultraviolet light at which is absorbed by the target chemical(s). After absorption of the appropriate wavelength of light, a highly reactive compound called a radical is produced. Given the right conditions in the reactor, these radicals are produced very quickly and will instantly break-down to carbon dioxide, water, and chloride, in the case of chlorinated compounds.

The UV Lamp is physically isolated from the reactor chamber by means of a Quartz Tube. The surface of the Quartz Tube is wiped clean at regular intervals by a air-actuated Transmittance Controller. The power required to drive the UV Lamp is supplied by a high-voltage Rayox Power Supply. Blower assemblies mounted at the top and bottom of the Rayox Reactor are used to blow cooling air across the electrical connections to the Lamp. Ultraviolet shielding is designed into the Reactor assembly. Sampling ports will be provided at appropriate points in the system to allow for analysis of treated water and ensure that the water is decontaminated prior to discharging. The Reactor is fitted with a drain line and drain valve for draining of the Reactor for maintenance purposes.

The System operated under control of a Programmable Logic Controller, or PLC, which monitors various sensors, adjusts parameters accordingly, and displays status information. Various interlocks and alarms make the system fail safe both for safety of personnel and the quality of discharged water. If, for example, a UV Lamp fails, an alarm is activated and the system is placed in recycle mode or automatically shut down.

There is minimal operator interaction required to run the System once on-line. Various controls and displays available on the Control Panel are used to control and operate the system.

Day-to-day operation of the facility will require a routine check of the control panel for lamp failure and changes in UV intensity, and a visual inspection of the channels of chamber to check for accumulation of solid material. Maintenance of the system is usually confined to routine component replacement, annual lamp replacement, and periodic cleaning of the quartz jackets.

The system will incorporate means for the following routine maintenance:

Daily

- Check UV monitoring device for UV intensity
- Check lamps for proper operation

Weekly

- Check for leakage around quartz tubes
- Calibrate UV intensity meter for proper sensitivity.

2 - 6 months

- Clean interior of UV Reactor

- Clean contacts on bulbs
- Check fail-safe devices for proper operation

Yearly

- Replace bulbs

Spares and Service

Included in UV equipment packages will be the minimum spares requirement. This will be 10 percent of the total installed number of lamps, quartz jackets, ballasts, and fittings.

The services of the UV manufacturer during the installation phase will be specified for inspection of the general installation, for equipment start up and for operator training. After-sales service will be available from the manufacturer using factory trained technicians.

The lamp tubes used in the system will be specified generic type and not customized in any way that would prevent the replacement by lamps from another manufacturer.

Changing of lamps and sleeves will be capable of being performed by the operating personnel at the plant. Modules requires to be returned to the factory for lamp replacement will not permitted.

Operator Safety

All UV systems will be designed to prevent casual exposure to the ultraviolet radiation and the equipment bear legends advising that safety glasses should be worn in the area. It is also recommended that full face masks be employed when working the equipment. Contractor and operator training and O&M manuals will

alert operators that each lamp in the UV module is a powerful source of UV radiation. UV radiation can cause series damage to unprotected skin and eyes, but is safe when the proper precautions are taken. The best protection is to prevent exposure to UV radiation. The UV modules pose no health threat when submerged and in the support racks but should be turned off when removed from the racks to prevent exposure to UV radiation. If it becomes necessary to work with an open source of UV radiation, gloves, protective long clothing, and UV face shield should be worn. Ordinary eyeglasses are not adequate protection. Neither are safety glasses with plastic lenses, or goggles that do not cover the entire face. No part of the body should be exposed to UV radiation and looking into a burning UV lamp and or exposing one self to a burning UV lamp can damage eyes and skin.

Individual UV modules, vertical or horizontal, should be protected with ground fault circuit interrupters (GFCI) to protect the equipment in the event of the entry of water. This is particularly important in the case of horizontal system because of the submergence of the ultraviolet lamps.

Other safety aspects to consider include safety railings, electrical interlocks, remote operating consoles, and adequate electrical wiring and waterproofing.

Control and Monitoring

In any ultraviolet reactor the operator is protected from casual exposure to the UV light with screens. Therefore, the control panel will provide all the information needed to determine the status of the system. The UV equipment system will incorporate the following status information:

- Individual lamp condition
- Ultraviolet intensity
- Lamp life

The first two incorporate alarm warnings which can be used for remote indication to a variety of external monitors.

Individual Lamp Condition

The control panel will incorporate an LED indicator lamp for every ultraviolet lamp in the system. These indicator lamps are illuminated all the while the UV lamps are in the "on" condition. Coupled with the indicator lamps is a lamp failure indicator, one per bank, module, or array of UV lamps. This lamp failure indicator is normally off and will only illuminate in the event that a UV lamp fails. The lamp failure indicator alerts the operator to a failed lamp condition and the lamp indicator identifies precisely which lamp has failed.

Ultraviolet Intensity

Ultraviolet intensity gradually diminishes. It is important to know the condition on a continual basis. A UV intensity monitoring probe is mounted in a representative position and measures the light emitting from a UV lamp through a quartz jacket and through a set thickness of water. Since the UV intensity decreases for lamp depreciation, quartz jacket fouling, or a change in water quality, this probe position will monitor any combination of these effects.

Lamp Life

Ultraviolet lamps naturally depreciate over time. It is necessary to measure and record the period of time the lamps have been in the "on" condition. Each bank, or array of UV lamps in the system will be equipped with a non-resetting elapsed time meter.

The output from this probe will be displayed on a meter. This is used in conjunction with three indicator lamps, for example, green registering a safe

intensity level, amber registering function in the low end of the safe range, and red registering operation outside the safe range.

To check the operation and calibration of the system, "push-to-test" buttons are provided whereby the operator can substitute the output of the UV probe for signals corresponding to two scale deflections of the meter.

Cleaning Methods

Water often contains organic and inorganic material. These can form a coating on the quartz lamp jackets in the UV reactor. Fouling of the quartz surfaces will produce reduced efficiency and reductions in UV intensity as measured by in-line intensity probes. An acceptable cleaning system must be capable of cleaning these surfaces.

The O&M Manual will describe the procedures used to operate the System.

The system will operate under the control of a PLC. If a fault should occur while the system is running the PLC will issue an alarm at the main Control Panel. Depending on the severity of the alarm the power to the system will be shut down. For some alarm conditions the system will resume operation after the condition has cleared. For other alarm conditions the system must be re-started manually as describes in this section.

There are a number of conditions that must be met before the system will begin operating, When the system is powered up, the PLC will check the conditions listed below. An alarm will be issued for each condition that is not met.

- Pneumatic air pressure is normal
- The reactor cover panels are in place
- The access lid in the top air blower duct is in place

- The temperature inside the reactor chamber is normal
- The moisture sensor does not detect water beneath the system
- The temperature of the Rayox power supply is normal
- The emergency stop button is not engaged

In addition, should any of the above conditions fail while the system is operating, then the system will shut down.

6.2.6 Carbon Adsorber Installation And Start-Up

The carbon adsorbers will be installed in accordance with the written instructions of the manufacturer. Also, the work will be done with the recommendations of the manufacturer's representative.

Media will be loaded by carbon slurry. The activated carbon will be transferred between vessels at a rate recommended by the manufacturer. Services will be provided by a representative of the manufacturer who is experienced in the installation, adjustment, and operation of the equipment. The representative will observe and recommend the installing, adjusting, and testing of equipment.

The manufacturer will conduct training. The training will be for designated operating, maintenance and support staff members. The training period will be during normal working time. The training will start after the adsorbers are functionally complete but prior to final acceptance tests. Field training will cover all of the items contained in the operating and maintenance instructions.

All products will be carefully inspected for defects in workmanship and material. Debris and foreign matter will be cleaned out of valve openings and seats. All operating mechanisms will be operated to check the proper functioning. All fasteners, nuts and bolts will be checked for tightness. Valves and other

equipment that does not operate easily or are otherwise defective will be repaired or replaced.

All tanks will be tested for water tightness at the fabricator.

After installation of the activated carbon adsorption system, operating tests will be conducted. These will assure that the system operates properly. Any deficiencies revealed during the tests, will be corrected.

Operating Instructions

The adsorption system is a unit consisting of six (6) vertical pressure vessels, operating as three (3) parallel pairs of two (2) vessels in series. Each vessel contains 20,000 pounds of granular activated carbon (total of 40,000 pounds per system). The vessels are complete with underdrain. Face piping and carbon transfer piping is shipped loose for installation in the field. The adsorber vessels are free-standing vessels, with the central piping assembly preassembled.

After connecting the influent and effluent piping to the system, the vessels can be operated in a series or parallel configuration. Granular activated carbon will be delivered to the site in bulk trailers for unloading directly as a water slurry into an empty adsorber.

Extracted groundwater will be pumped to the adsorption system at a flow rate compatible with the design capacity of the unit.

Flow is directed into the top of the first vessel in each set (lead adsorber) and flows down through the carbon. From the bottom of the lead adsorber, the stream flows into the top of the second adsorber (polish adsorber).

When the carbon in a vessel is exhausted, an empty trailer is sent to the site to remove the load of spent carbon. The carbon will be returned to a vendor for thermal reactivation.

The spent carbon is transferred from the adsorber to the bulk trailer by first filling the adsorber with water. The adsorber is then pressurized using compressed air as the motive force to facilitate the carbon transfer to the trailer.

Once the spent carbon transfer operation is completed, a charge of fresh carbon can be transferred into the empty adsorber. This is accomplished by filling the bulk trailer with water and using a water cushion in the adsorber. The bulk trailer is then pressurized with compressed air to facilitate the carbon transfer into the adsorber.

In parallel operation, when one set of vessels is taken out of service, flow is directed to the remaining two (2) sets for uninterrupted operation. After the first set is emptied and then filled with fresh carbon, it can be placed on-stream.

Differential pressure switches are supplied to measure the pressure drop across each bed. Pressure drop through an adsorber system is a function of many factors:

- Pressure drop through the carbon bed(s).
- Nozzle and piping pressure drop.
- Mode of operation (series or parallel).
- Flow rate, viscosity, and density of the liquid.
- Solids build-up on top of the bed.
- Bacteria growth or chemical precipitation in the bed.
- Gas build-up in the bed.

Backwashing/backflushing is usually required when the pressure drop across an adsorber increases by 5 to 10 psi during the adsorption cycle.

Standard units come equipped with a 45° internal cone. This internal cone offers many advantages, such as ease of carbon removal and good flow distribution through the nozzle underdrain. Since the internal cone is not part of the exterior vessel, it is designed to withstand a working differential pressure of 20 psi. Note that this differential pressure is less than the maximum allowable working pressure (MAWP) for the vessel. High cone pressure differential could exist due to:

- Unlimited backwash water flows. This is probably the most dangerous situation since the cone is weaker in the upflow direction.
- Nozzle pluggage due to precipitation, fines, or bacteria. This could happen either in the backwash or process operation.
- Unlimited process flow.

Do not operate the system unless the differential pressure switches on each vessel are operating properly. A high differential pressure that could cause damage to the internal cone could go undetected.

To prevent damage to the system in the event that the pressure limitation of the vessels is exceeded, pressure relief devices are provided in the adsorber vent lines.

After startup, records will be kept of pertinent data such as flow rate, pressure drop across each bed, total dissolved solids, temperature, pH and specific organic constituents.

6.2.7 Sludge Removal

Sludge will be removed from the sedimentation tank (IT-103). The sludge will be 30 pounds per 15,000 - 17,000 gallons of backwash water from the Greensand filter. There will be three (3) backwashes per day. This results in 45,000 - 52,000 gallons per day and 90 pounds of solids.

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